PAYMENT BY RESULTS

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INTRODUCTION. ORGANIZATION
RATE-FIXING

BY

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WITH DIAGRAMS

LONGMANS, GREEN AND CO.
LONDON ✦ NEW YORK ✦ TORONTO
1934

LONGMANS, GREEN AND CO. LTD.
39 PATERNOSTER ROW, LONDON, E.C.4
6 OLD COURT HOUSE STREET, CALCUTTA
53 NICOL ROAD, BOMBAY
36A MOUNT ROAD, MADRAS

LONGMANS, GREEN AND CO.
114 FIFTH AVENUE, NEW YORK
221 EAST 20TH STREET, CHICAGO
88 TREMONT STREET, BOSTON

LONGMANS, GREEN AND CO.
480 UNIVERSITY AVENUE, TORONTO

First published 1924.
Cheaper Reissue April 1934.

Made in Great Britain

PREFACE

In the pursuit of efficiency in production, much attention has been, and is still being concentrated upon the methods or systems by means of which payment of wages is made in accordance with the results as shown by the amount of output obtained. While there can be no doubt as to the efficacy of linking up wages and output in this manner, the most careful consideration is necessary in so doing to ensure that not only will the application of the principle be right, but also, what is, perhaps, of more importance, that the introduction of the system chosen shall not be attempted until the conditions obtaining in the workshops are such as to render its successful operation possible.

While the history of payment by results as regards influencing output in an upward direction is undoubtedly good, yet the effects of its application, as evidenced by the attitude adopted by the Trade Societies, are deplorably bad and, in the interests of industry itself, it is a problem of the first importance, to effect an immediate and permanent improvement. For this improvement to be possible, however, it is necessary, first, to discover the causes of the trouble and, in making this investigation, it will frequently be found that the apparent causes are not the real ones.

That the will exists to discover and to remove any conditions which are detrimental to smooth working is in no doubt. Many firms are willing to make real concessions to ensure that payment by results shall be accompanied by fair and equitable conditions and it would appear, almost, from the various suggestions put forward, in some cases by employers themselves, that most of the past troubles have been caused by a lack of good faith as evidenced, for example, by the cutting of job rates. The author has been forced to the conclusion, however, that, in spite of superficial beliefs, the question, deep down, is one of economics rather than of good faith, and that, when output is low, the right remedy is not, necessarily, payment by results, which, by inference, places the responsibility for low output upon the workers, but rather, is the acquirement, by management, of efficient production knowledge and the exercise of suitable production control. He believes that much of the trouble which has been experienced is due to the wrong use—the abuse—of payment by results, and has not been caused by its legitimate use.

It is suggested that a different outlook is required if real efficiency,

as reflected by production at economic cost, is to be achieved; that efficient output is not, never was, and never can be a matter of workmen's energies alone. If this view can be accepted as correct, the use and universal recommendation of payment by results as the *open sesame* to efficient production stands condemned. The object ought to be efficiency in the broadest possible sense, but in many cases this, the real need, is overshadowed by the belief that efficiency is certain under payment by results; the object then sought is payment by results only, under which improvement rather than efficiency becomes possible. When a system of payment by results is introduced the existing rate of output is almost bound to be reflected in the job rates fixed, and as this rate is unsatisfactory so *will the approach to true efficiency be barred excepting by cutting job rates.*

One of the most important needs in the obtainment of efficient production, if economic cost is to be the criterion, is an accurate diagnosis of the position and then the application of the appropriate remedy. Even as it would be foolish to treat stimulants as the universal cure for paralysis, so also is it unwise to expect efficiency, by offering workmen an inducement to work harder, when the whole works may have been paralyzed by inefficient organization and administration. A new orientation of the position is required. When the output or cost position in a works is unsatisfactory, the first consideration ought not to be workmen's energies but, rather, organization. If payment by results is to be introduced, the first step should be a review of production possibilities, with the object of removing obstructions. Like an express train, payment by results requires a clear road; without this, it loses its character and can, itself, become an obstruction to progress as do other "slow trains."

The object of the author in writing this book is to indicate those steps which are necessary, to correct the weaknesses by which production can be affected, and to avoid the numerous pitfalls which seem to beset the introduction of payment by results. He believes that estimates of output are of more importance than job rates, and the object in the chapters on production estimating is to show how to analyze and to estimate rather than to give tables and general information, the value of which can be affected so much by local considerations. No claim is made to have written anything original, but that which is written is the outcome of many years' observations in connection with the obtainment of production, both with and without the aid of payment by results, and if the book should prove to be even a slight contribution to the literature on the subject which already exists, the effort made will not have been in vain.

The author acknowledges his indebtedness to Mr. A. W. Boase of Erith for the reading of a portion of the MS. and to Mr. T. E. Riddle of Birmingham for a similar service when in the proof stage, and to both for the many valuable suggestions made. His thanks are due also to his nephew, Mr. R. Powell of Coventry, for making the diagrams with which the book is illustrated.

J. E. POWELL.

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CHAPTER I

THE GENERAL SITUATION

As a result of competition in the commercial world in which the individual consumer of all classes is a controlling factor, the administration of industrial concerns to-day is becoming increasingly complex, and the closest attention to the efficiency of the product manufactured and to the cost of production is absolutely necessary if commercial existence is to continue.

The conditions under which industry is now carried on are vastly different from those existing a generation ago; something akin to a revolution has taken place, both on the commercial and on the industrial side. Where contracts are concerned, the old method of "time and lime" payment, cost plus profit, has been discarded wherever possible. The common practice to-day is that of firm tender, and here, because of the influence of competition, the margin for contingencies is often reduced to a minimum and, in some cases, is left out altogether, profit being affected in consequence.

While the situation in the industrial world will always reflect the demands of the consumer, these in turn are influenced by economic considerations which affect manufacturer and worker alike. The keenness of competition is such, both at home and abroad, that the manufacturer, in endeavouring to meet the requirements of the consumer, is forced to consider carefully the cost of production, and one of the chief elements in the cost of production is the cost of labour. Cost of labour is affected, amongst other things, by the worker's rate of output, and this brings into review his ability and willingness to produce at a satisfactory rate. The rate and cost of production must be such that will enable the articles made to be offered for sale at a price which will attract purchasers and, at the same time, make it possible for a profit to be shewn.

Then as the manufacturer is successful in obtaining production at economic costs, so is he likely to secure further orders and, by so doing, be enabled to keep his works fully occupied, these conditions tending to facilitate the obtainment of still further orders.

The worker on his side seeks from the manufacturer adequate wages in return for the services rendered, accompanied by continuity of employment. He has no responsibility for production,

either for its volume or its quality and stands to suffer no financial loss whatever may be the results of the year's trading, even should any loss, which may be sustained, be wholly connected with labour.

This gives in the barest outline one phase of the industrial problem of to-day, and that phase exists independently of whether the system of payment for the services rendered by labour in the shape of workmanship, is based on time or results.

If the influence of the main factors which can affect industry be examined they will be found to be influenced by the following considerations:

The Consumer seeks—low prices—quick delivery.

The Manufacturer seeks—large profit—repeat orders.

The Worker seeks—high wages—continuous employment.

The problem in front of the manufacturer is to reconcile these contending interests so that neither will predominate to such an extent as to prejudice the other. The clash of interests would appear to be almost irreconcilable, and while this is not really so, the experience of the past tends to suggest this.

As competition increased and the conditions under which contracts were placed changed and became more stringent, manufacturers, recognizing that the best results in the shape of output were not obtained under the time system, and with the object of controlling labour costs, commenced the practice of remunerating workers in accordance with the amount of work done. This method has been used for many years in different forms, and with varying degrees of success; in some industries the practice is almost universal, in others it is only partially adopted, while there are instances where its use is considered to be impossible. Wherever it has been used, however, the main objects, increased output with accompanying increased earnings, have been achieved, and there can be no doubt that costs have been reduced thereby.

Unfortunately at the same time, as a consequence of their experience under systems of payment by results, grave objections have been generated in the minds of the workers and, in the engineering trades, these have assumed such serious proportions, that it is a matter of first urgency not only to remove the causes, if that be possible, but also to prevent their recurrence.

It is somewhat strange, however, that a method of payment of wages which has been devised with the object of obtaining efficiency in rate and cost of production and which remunerates workers in accordance with the results obtained, should have failed so lamentably as to be the cause of the dissatisfaction which has been in evidence. It would appear that there must be something fundamentally wrong with the principles underlying payment by results or with some or all of the systems in use, or the trouble must lie elsewhere and payment by results be the apparent and not the actual cause of the unrest.

Theoretically, there can be nothing the matter with the principle of payment by results, more particularly from the worker's stand-

point, when the time rate of wage is guaranteed. It is a case of all profits and no losses so far as the worker is concerned, and human nature is such that an appeal of this kind is not likely to be objected to excepting for some important reasons. To object is almost akin to a firm whose tender for work has been accepted, objecting to the customer's voluntary guarantee of a minimum profit.

A number of complaints, however, are made by the workers, although these may be reduced mainly to two.

1. That job rates are cut.
2. That continuity of employment is affected.

Taken together, the two complaints make a problem of the first magnitude and, unfortunately, they are well founded. In respect to the first complaint mentioned, the Report of the Departmental Committee appointed by the Board of Trade to consider the positions of the Engineering Trades after the War may be quoted.[1] This Committee was appointed in 1916 and after receiving evidence from thirty-one different branches of the Engineering Industry, completed their Report in 1917.

With reference to " piece-work " the Report reads as follows :

"**Piece-work.** In order to enable the expert workman to earn during the best years of his life the maximum possible return, it would seem that piece-work, or a bonus system on time work, ought to be the foundation as far as possible of all employment.

The Trade Unions have in the past been very reluctant to admit piece rates. Indeed, even now, some of the Unions forbid their members to accept piece rates where these have not previously been in force, and, where piece-work has been started, the members are asked to discourage it as much as possible. It has also been evidenced to us that cases have occurred wherein should the men earn more than time and a third they have been fined by their Union—and as emphasising the possibilities that can follow the removal of restrictions there were cases where, despite these, either imposed or encouraged by the Unions, makers said they could produce machines of a given type at lower cost in England than in the United States.

There has been in the past, no doubt, a grave disadvantage in the regulation of the prices paid for piece-work which has been the fault of the employer and not of the workman. The feeling seems to have been widely held that if a piece-worker drew between time and a quarter and time and a third, that was the most he ought to earn under the piece rate. Amongst some of the smaller employers this idea is still held, and the consequence has been that the workman has naturally developed a great distrust of the system, which, although in appearance encourages him to use his best endeavours to secure the maximum reward of his labours, has, in effect, only encouraged him to produce a maximum subject to a limitation of a wage as stated.

The workman has restricted his output accordingly. We are glad to think that the injustice of the application of this system is widely recognised, and that few employers of any standing have recourse to a system of cutting piece rates, a system which was prevalent in the old days to such an extent and without justification, that piece-work was brought into disrepute. Indeed, certain Employers' Associations have regulations against this practice. We are of opinion that a piece rate once fixed, and proved to be reasonable after fair trial, ought not to be disturbed, except by adjustment through agreed rise and fall of wages or in very special circumstances—such as the introduction of an improved machine or method of producing the same article.

[1] Reproduced with the permission of the Controller of His Majesty's Stationery Office.

Naturally, a piece rate on a new article cannot be arrived at with any degree of certainty until its production has continued for some time. When the work has once been reduced to a piece rate, it should not be capable of being disturbed, except by adjustment, without the consent of the local Employers' Association and the Branch of the Trade Union affected.

Unfortunately, the difficulty in fixing piece-work rates is greatly accentuated by the fact that the men work slowly as long as the job produced is on time rate so as to obtain the fixing of a higher piece-work rate."

"On Maximum Output and High Wages" the Report continues as follows:

"**Maximum Output and High Wages.** In the future it will be all important that output should be encouraged to its maximum. We cannot see that this can be expected to be realised unless the workman has, as he is entitled to have, the fullest assurance that what he earns he will get, and that his best efforts will not be used to cut down his best earnings. There is no question that the engineering plant in this country was excessive in relation to the total work that was produced from it, and it is only since the war that national circumstances have demonstrated what a machine is really capable of doing when worked to its full capacity and without restriction. This is realised by some of the Unions, and in a state of peace between Capital and Labour it would undoubtedly be proved that the largest output in quantity of material possible for the money received was the true basis of high wages."

This Report, because of its authoritative nature, constitutes an indictment of the gravest kind and is in line with the complaints made up and down the country. As a consequence of this general experience, much attention has been directed to the question; the best brains on the sides of both employer and employee have been brought to bear upon it; many outside influences have been at work; new systems have been devised; comprehensive systems of making and hearing complaints have been introduced; minimum bases of earnings, in addition to guaranteed time rates, have been laid down, all indicating a recognition of the seriousness of the situation and a desire for its improvement.

At the same time, it cannot be too strongly emphasized that the remedy will not be found in good intentions, nor in agreements, nor in systems; except the causes of past failure are ascertained and efficiently provided against there will be no sound foundation on which to build, and the future will most likely prove to be nothing more than a repetition of the old mistakes, because economic forces can render ineffective any agreement and nullify the best of intentions. There is evidence on every hand that the trouble with payment by results is due to the fact that the rates paid for the results obtained have not been economically sound.

The importance of the economic factor was, perhaps, never more plainly demonstrated than during the years immediately following the Great War; then what appeared to be the promise of a wonderful boom in trade fell away to one of the most disastrous periods of depression this country has ever known. While other factors were present, high cost of production was responsible to a very considerable degree, and this had perforce to be remedied before any adequate permanent improvement could take place.

What are the evidences that the trouble with payment by results is economic? It is unnecessary to argue to-day that the lower the cost of an article the greater is its demand likely to be. This has been proved over and over again and, wherever the cost of production is higher than it need be, the consumer seeks other sources of supply and costs must either fall or business be lost. The market value of articles in general use is to some extent what they ought to cost rather than what they have cost; other considerations obtain such as demand and monopoly, but in course of time these are affected by the one first mentioned.

Reverting to the workers' chief complaints that job rates are cut and continuity of employment is affected, it is suggested that these complaints are rooted in common soil and are but different expressions of the same trouble. It is suggested also that the responsibility for the cause of these complaints must be shared by both manufacturer and worker, although perhaps not equally, and that, further, in the very cradle of payment by results, according to many of the apologists for the various systems, have lain features which make trouble almost unavoidable, in the shape either of industrial discontent or economic failure. The success of payment by results has been its curse and is a reflection, in some instances, of the ineptitude which has characterized its use. The requirement is efficient cost; the object sought has been increased output only, and the two are vastly different.

In considering the cutting of job rates it is desirable that the object underlying the use of payment by results should be kept in mind, otherwise it is possible to obtain a wrong impression. The object in the past has been to induce increased output by offering opportunities for increasing earnings, and it is not straining the point to suggest that the manufacturer, as a business man, is not unaware of the fact that if the inducement be removed—and a reduction of job rates has this tendency—the effort put forth to secure increased wages, and therefore a larger output will be likely to be lessened and thus defeat the end in view. It will probably be found when job rates have been cut, that this has been due to their having been fixed too high, and their reduction will have been sought because of the pressure of competition—difficulty of obtaining orders—or for the purpose of making both ends meet.

It is possible, of course, for reductions in job rates to be sought solely because of the greed for gain, and there is no doubt that there are cases of this kind, where the business acumen of the manufacturer has been subordinated to an unintelligent greed; these cases are however, comparatively speaking, but few and are occasional rather than general; the average manufacturer, as well as the average workman is a reasonably honest man and is desirous of following a straightforward policy. If this view cannot be accepted there is very little hope for future peace, because the question becomes one of human nature, and no class holds a monopoly either of its virtues or its vices. On the other hand, if this view be accepted

one is forced back to the conclusion that reductions have been made for economic reasons, and in the interests of the business rather than in those of any individual, in which case the worker as well as the manufacturer will have benefited.

Viewed from this standpoint, the cutting of job rates would be robbed of some of the objections with which it has been clothed, but it would still not be justified, neither can the practice be supported. At the same time, however, it is necessary, before an unqualified condemnation is made, that the basis on which job rates have been so often fixed shall be considered, for the purpose of ascertaining what bearing such basis has on the situation.

If the history of payment by results be examined it will be found that, in the early days, and in some instances it is the case to-day, job rates have been based on the times actually taken, and the devisors of some of the systems in present use still advise that the job rates shall be based on " the average time which a man of average ability takes to do the job under time rate conditions." The existence of this practice is also referred to in the Report quoted on page 4. There it will be noted that " naturally, a piece rate on a new article cannot be arrived at with any degree of certainty until its production has continued for some time." " Unfortunately the difficulty in fixing piece-work rates is greatly accentuated by the fact that the men work slowly as long as the job produced is on time rate so as to obtain the fixing of a higher piece-work rate."

Thus job rates have been used to make a more or less permanent record of the rate at which men produced when working on the time system, and, in fixing the job rates in this manner, the manufacturer has actually placed on record his willingness for the rate of output obtained in the past to become the basis of the costs of his future productions. If the costs, resulting from the use of this rate of output, proved to have a crippling tendency on future productions it would indicate that the rate of output obtained under the time system was lower than it should reasonably have been and, therefore, was not fitted to be used as the basis for such a momentous purpose. Consideration of the second complaint will shew proof that this was so.

In complaining that the use of systems of payment by results causes unemployment, the workers are ventilating a matter which to them is of the utmost importance, because unemployment means the lack of opportunity to provide food and clothing, not only for the worker himself, but for his wife and his children, a matter which affects the first law of nature, self-preservation. At the same time it must not be overlooked that the worker can be a very serious contributory cause of irregularity of employment, and to some degree he shares the blame for this outcome of payment by results of which he makes complaint.

Payment by results will most certainly not reduce the amount of work available; its influence will be seen in the opposite direction: therefore, if continuity of employment be affected, it must

be, and to that extent only, the amount by which the rate of output obtained previously fell short of that which was possible. There is no doubt whatsoever that this is what happens, and if reference be made to Chapter II. ample evidence will be found in examples which have come under the author's personal notice, being selected from a number of works.

In voicing these complaints the workers, who set out to blame the manufacturers, not without reason, succeed in calling attention to a state of affairs for which they are partly responsible. It is not unlikely that if it had not been for the increased output and reduced costs secured by the use of payment by results, of which complaint is made, some measure of commercial failure would have resulted, making the position, as regards unemployment, worse than under payment by results. Under payment by results, costs of production will have been reduced and the prospects of obtaining orders will have been increased accordingly; under the time system, if orders be lost through costs being too high, the application of remedial measures is too late, the firm will have been passed by prospective customers. The fact that the complaints made have had a solid basis goes to support the statement that the past troubles with payment by results have been due to economic causes.

It is useful to know that the rate of output obtained is lower than it ought to be, but that knowledge alone does not help toward a solution. That fact was recognized long ago by those who devised the various methods of remuneration; where they failed, was in not ascertaining the real reasons for the deficiency known to exist, although as a result of their labours we are now in a much better position to do so. In recognizing that output was low, endeavours were made to obtain improvements, and from that standpoint steps were taken which were calculated to ensure them. Unfortunately the extent to which the situation could be improved was not equally recognized, and the methods employed, while achieving one desired object, did not ensure efficiency of cost.

It is possible to obtain efficiency of output without ensuring efficient cost, and what is of more importance, *efficient output can be obtained at such a price that efficient cost is made impossible.* This is the logical result of pursuing a policy of improvement without obtaining first an adequate idea as to what constitutes efficiency, and that is the position into which many present-day manufacturers have drifted.

A simple illustration will indicate the position. Let it be assumed that the time taken in the manufacture of a component part of a machine is 12 hours and that payment by results is introduced, the time taken being used as a basis for the job rate, which for a time rate of 1/- per hour will be 12/-. Let it be assumed further that a fair time for the work is 6 hours, instead of 12 hours, and that eventually it is done in this time; efficient output may then be said to have been secured, but the basis of the cost will ever be

that of the inefficient rate of output previously obtained, 12/- instead of 8/- (8/- includes one third on the time wage of 6/- to allow for extra pay under payment by results), and, if competition presses, no remedy exists other than that of cutting the job rate.

Both past experience and present-day facts point to the need for quite a different policy. The old policy, stated in plain language, indicates an attitude of permission to produce; this is altogether too weak and ought to be and, it is believed, can be replaced by another and more definite policy—control of production. Production must not be allowed merely to evolve either in methods or rates. Because of the existence of the human factor, an identical rate of output cannot be obtained from each person with the same close precision that obtains with the mechanical output of machines, but this is not to say that no control is possible. Manufacturers must have an adequate idea of what is possible as regards rate of production and insist on its obtainment, and can no longer allow themselves to be dependent upon that rate of output which workers may choose to give or which lack of good organization permits.

The policy is bad for another reason. It is wrong to assume, as a matter of course, that low output reflects the indolence of workers and that the only way by which output can be increased is to introduce payment by results, offering, thereby, what under the circumstances is little more than a bribe. Production can be affected from so many different directions, and in very many cases the increased output, which has followed the use of payment by results, is due to improvements in organization and to elimination of delays which are the direct result of workers' suggestions, the object being the removal of obstacles to their earning capacity.

It is the manufacturer's business so to organize his works that efficient output is possible; if he does not, and knowingly or unknowingly attempts to achieve this by a system of payment by results, then, in the job rates fixed, and so long as those job rates are maintained, he will be paying the cost of improving his organization over and over again. There is no help for it, and it is the price which must be paid for inefficient control and for the use of the wrong remedy. An illustration will shew how unnecessary it is to mortgage the future in this manner.

In one department of an engineering works, a certain type of cord was being manufactured. Although the effects of competition were being felt, the demand was a growing one and the manufacturer found his stocks were being very much depleted. He was selling at the rate of 12 miles per week and was manufacturing at the rate of 10 miles only. The matter was gone into and it was found that the bottle-neck or the controlling factor in the output was certain machines, and that these were not kept running more than one half of the time. This was remedied, and with the addition of 3 per cent. in labour—and no payment by results—the output was increased from 10 miles to 16 miles per week. The workmen raised no objection to the improvements in organization

which made this possible, but, unfortunately, the manufacturer was then unable to dispose of the whole of the output and short time was resorted to.

If, as had been desired, payment by results had been introduced as the medium whereby increased output was to be obtained, the comparative shortage of work, ending in reduced hours, would have been attributed thereto, while, on the other hand, job rates would most likely have been on the high side and the reduction of costs required made more difficult.

It will be worth while to compare what would have been the probable resultant cost if payment by results had been used in this instance, and the existing rate of output had been used as an approximate guide only. The output was increased by 60 per cent. ; let it be assumed that it was considered the output should have been 12 miles per week under the time system, and that this was made the basis of the job rate ; and that, further, 16 miles per week were obtained as a result of the inducement offered under the system of payment by results adopted ; the amount of extra pay secured thereby being $33\frac{1}{3}$ per cent. On a basis of 1/- per hour per man and 100 men originally employed the annual cost to the firm would compare as follows :

	Unsuitable Organization.	Improved Organization.	Payment by Results.
Weekly time wages -	£235	£235	£235
Weekly time wages for additional 3 % of men required under improved organization - - -	—	7.05	Assumed not to be required
Extra pay - - -	—	—	78.33
Total - - - -	235	242.05	313.33
Annual totals (50 weeks) - -	11,750	12,102.5	15,666.66
Cost per mile - -	23.5	15.12	19.58

Total annual saving on a basis of 800 miles produced by *not using* payment by results £3,564.

Had payment by results been used in this case as the medium for increasing output this annual saving would not have been possible nor the reduction in selling price which could be made as a consequence, and which brought a much needed and timely relief. On the other hand, the extra money paid to the workers would not have been for increased energy so much as for their assistance in improving organization. There is no doubt workers can help to improve organization and their help should be encouraged, but there are right and wrong ways of making payment for any services rendered.

When job rates are based on existing rates of output or when payment by results is introduced into an inefficiently organized and supervised workshop, the weaknesses, which are almost bound to exist, cannot fail to prejudice job rates, and by allowing this to take place, the cost of faulty organization and low output becomes embodied therein; then the extra pay earned is often, to a large extent, the result of improved organization, not necessarily of increased effort and this payment must be repeated again and again. No firm can afford to pay more than once for any service, but, in any case, if payments are to be extended on the instalment principle there should be adequate knowledge as to what is really involved in so doing.

The truth is, many works are overmanned for the amount of work produced, and whatever steps are taken to correct this error, whether payment by results or efficient production control, the experience must be similar, although it may vary in degree. Thus, if in a workshop, 40 men are necessary to do the work of 20, whatever may be the cause, so soon as that cause is removed there will be sufficient work for 20 men only; actually no change will have taken place in the amount of work available; the workshop will not have become "slack," but rather it will have ceased to be slack.

On the other hand, if a works be taken where output is low and payment by results is introduced for the purpose of inducing an improvement, what are the chances of obtaining efficient output and costs combined? What is to be the basis of job rates? To obtain efficiency in the two directions, the staff responsible for the fixing of the job rates will have an exceedingly difficult task. They will be met, probably, by the united opposition of the workers, and, in some works, of the staff, and the only means of making headway at all, in such cases, is to make the everlasting compromise, and split the difference. This is the history of many payment by result schemes, the administration of same often being a matter of diplomacy rather than the use of knowledge and the making of a straightforward open proposition.

The author remembers an interesting case where tenders were frequently invited for a certain spare part. The quotation from one firm was 10 shillings each and this was accepted. Later on from another firm 5 shillings each was tendered, the lower price being entirely due to the difference in the job rates. The methods employed were identical, and while the men who did the work for the first quoted firm congratulated themselves on "their good price" that same price effectively cut out the obtainment of further orders. Both firms used somewhat similar systems of payment by results.

It is possible to approach the question from many standpoints. That the use of systems of payment by results serves to improve output cannot be gainsaid; that it reduces cost is also the common experience; that it can serve to make future manufacture too expensive is also in no doubt. What is called for more than any-

thing else is production knowledge; what appears to be necessary, is a revolution in production management. Much is said of the worker's desire for an improved status. There is some demand in that direction, but much moonshine exists. What the individual worker, organized or unorganized, takes some note of is efficiency of control, not necessarily to be interpreted as that of a "bossing" nature, but rather the efficient use of his efforts and a fair, consistent and continued rate of remuneration.

It is believed that the average workman and the average manufacturer are reasonably honest men; that much of the trouble over payment by results is due to misunderstanding, both parties being at fault, neither getting right down to the real or to all the facts. Future troubles, however, will not be avoided by any number of good resolutions any more than they have been caused by deliberately bad faith. Economic conditions will operate and the criterion all the time must be efficient output reflected in economic costs of production. If these be obtained, together with the confidence and goodwill of the workers, any firm, whatever may be its method of remuneration, is to be congratulated.

Before a system of payment by results is introduced, many searching investigations require to be made, amongst these being—

1. The ascertainment of the existing position as regards rate of production.
2. Is payment by results the right remedy or is the improvement required outside its scope and do other remedies require prior application?
3. What branches of the work can be dealt with, and what will be the effect on those workers whom it may appear necessary to leave out?
4. What will be the effect on other workers of any grade; will wage values be brought into question?
5. What system is to be used; an individual or a collective system, and if individual, which one; if collective, on what basis?
6. What is to be the basis of job rates?
7. How will the system be linked up with the existing routine?

It has been suggested that much of the increased output obtained under systems of payment by results is due to the overcoming, by the workers themselves, of obstacles which are attributable to faulty organization or inefficient supervision. Faulty organization shews up in many ways—

Insufficient supplies of material;
Inefficient tools or supply of tools or other appliances;
Machines out of repair;
Unsatisfactory workmanship in previous operations.

All these are readily susceptible to remedies other than payment by results.

With the points mentioned given proper attention there should be some reasonable possibility of efficiency of output and economy of cost being ensured, as well as a fair measure of industrial peace.

It is after all nothing more than an intelligent application of the old adage, " Look before you leap."

The criterion however must not be merely the amount by which output has been increased or costs reduced. In some works an increase of 5 per cent. would reflect more efficient work than 50 per cent. in others. A very large increase in output reflects previous inefficiency rather than the virtues of the particular system in use, and instances have been known where output has been increased amazingly without reaching 100 per cent. efficiency, either of output or cost.

The improvements made are too often taken and used as proofs that certain systems of payment by results are the right ones or have certain advantages, but this is not necessarily any more correct than it is to blame payment by results for the faults which are really due to lack of suitable administration. The true criterion will be not to what extent the operation of the system has assisted the manufacturer to improve his organization and thus made greater output possible, nor in what measure it has tended to counteract the inefficiency of supervision, but rather what appeal the system makes to the ordinary worker, and what are its results calculated to be when tested by costs of production.

Ideas as to the value of the influence of payment by results, because of its wrong use, have become much exaggerated, and there are works where payment by results is treated as a synonym for efficiency. This is an unfortunate mistake, and there is no doubt that some firms to-day are finding the results of the operation of their systems of payment something in the nature of a millstone. What matters more than systems is knowledge of output possibilities, arrived at by an analytical examination of all the factors which can affect output. Without this there can hardly be an adequate idea of the volume of output which should be obtained, and the natural result is for output to become impaired.

To appreciate fully all aspects of the question it is necessary to consider from all standpoints how the different methods of remuneration can and do affect organization, workers' energies, and quality of workmanship.

CHAPTER II

SOME EXAMPLES OF LOW OUTPUT AND HIGH COST UNDER VARIOUS SYSTEMS OF PAYMENT

WHILE it is quite logical to compare the rate of output obtained when payment is made in accordance with results given, with those which have been obtained previously when the time system was in operation, the effect of such comparisons can be somewhat misleading excepting they be made with an adequate knowledge of the conditions under which the respective results were obtained.

There is no doubt that the increase of output which often follows the introduction of payment by results can be so great as to be almost incredible, although, to the thoughtful observer, such results present food for thought of a kind which is not always in keeping with the chorus of congratulations with which they are usually received.

Nothing is more deceptive than half-truths, and it is hardly possible for the whole truth to be gleaned from a plain statement as to the times variously taken under different systems of payment. In the interests of manufacturer and worker and of the industry itself, the true position ought to be known, otherwise wrong impressions are likely to be created and firms may be encouraged to start payment by results without realizing all that is involved, it being assumed, sometimes quite wrongly, that payment by results is the sole reason for the increased output which may have been obtained elsewhere, and is thus the right policy for them to pursue. Then, in order to avoid the adoption of a policy which may be wrong, because its premises are at fault, it is essential to consider not only results but, also, reasons.

Some time ago payment by results was introduced into a fitting shop, and a fitter was asked if he would accept a price for his job. His reply was, "Yes, but you'll have to take the other chap off, there is only enough work for one man." Four times as much work was done as a result, but approximately one half of the increase shewn was due to the unnecessary man being taken off. In another instance, it was the practice for two fitters always to work together; even if the jobs were both light and simple, the time of both men was always booked against the job done. Payment by results

was introduced and the practice of two men working together on one job was discouraged. It was arranged, wherever possible, to provide two adjacent jobs so that mutual help could be given if required. The old practice soon died a natural death, but the increased output, as shewn by the reduced hours booked, was due, in many cases, as much to the alteration in practice as to the influence of payment by results.

The increase in output obtained under payment by results rarely reflects pro rata the increased energies of the workman, nor is it the result of the appeal of the systems in use to the men as workmen; in part, it is quite often due to the overcoming of obstacles to production in the shape of faulty organization—the appeal to workmen as organizers.

With a view to emphasizing the importance of this question a number of examples of actual jobs will be quoted, giving, not only particulars of the output obtained, whether the same remained low or was increased, but also the accompanying reasons, indicating at the same time how costly increased output can be when the wrong methods are used. Each one of the examples quoted has come under the author's personal notice and are culled from records dealing with many different works and products.

EXAMPLES OF LOW OUTPUT UNDER THE TIME SYSTEM

No. 1. **Machining Work.** In a works, manufacturing motor accessories, the need for reduced costs, owing to the influence of competition, caused the directors to consider by what means output could be increased, and they were disposed to think that payment by results would be the surest method. Before any steps were taken in this direction, however, they consented to an investigation being made to ascertain what their shop conditions actually were. The result of this investigation disclosed the following facts:

1. That the rate of working was good.
2. That output generally was low.
3. That there was insufficient work to keep the men fully occupied, they having to wait for the next job.
4. That, through bad shop organization, the batches of work handled were smaller than need be.
5. That no use was made of the production statistics provided, otherwise these faults would have been disclosed.

The defects disclosed by the investigation were given attention and a considerably increased output was obtained. The diagrams shewn on the opposite page, Fig. 1, give examples of the hourly outputs formerly given, compared with those proved to be possible. The attitude taken by the shop foreman was that because the wages rates were low the actual differences in cost were not great; it was necessary to point out that a difference between 20 and 30 seconds per piece taken on an operation was of as much relative importance as though hours instead of seconds were involved.

In any case, oncosts were affected and in these works they were heavy.

Payment by results was not introduced.

Diagrams Shewing
Inefficient Output under the Time System
As indicated by actual and estimated figures.

OPERATIONS.

Turning.

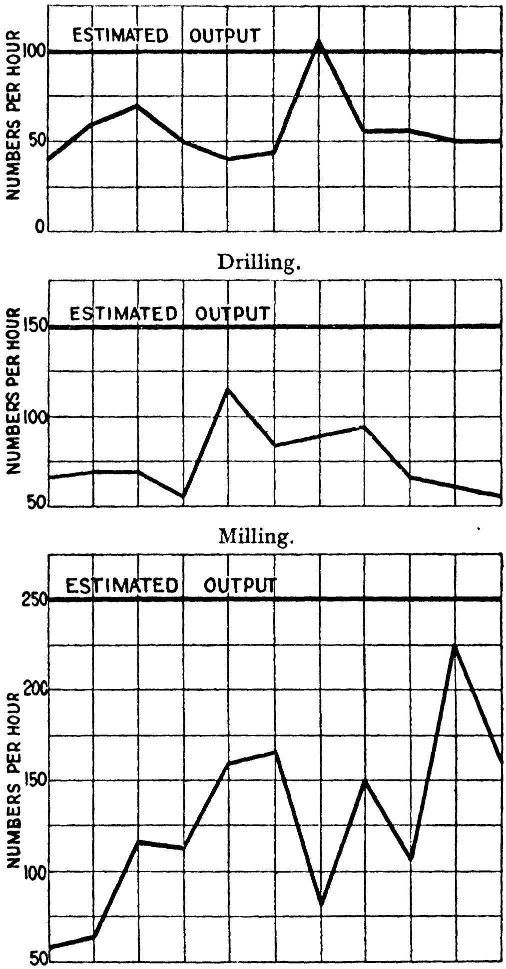


FIG I.

The principal reasons for the low and varied rates of output were faulty organization and an insufficient supply of work. A period of approximately three months is covered.

No. 2. **Fitters' Work.** Operation—Fit key and propeller to shaft.

The diameter of the shaft was $3\frac{3}{4}''$, and the length of the taper on which the propeller was to be fitted was 8″. The key and key-bed were machined as also was the key-way in the propeller, and the operation included fitting one key to the shaft, then the propeller to the shaft, making such adjustments as were required to secure a good sound fit.

The time taken was 59 hours, the fitter having the assistance of an apprentice, whose time is not included in the hours quoted above. The outside time value of the work done was not more than 10 hours. Ignoring the cost of the apprentice's time the results shew up as follows:

Actual cost - 59 hours at 1/- per hour - -	£2	19	0
Outside value - 10 hours at 1/- per hour - -	0	10	0
Amount by which cost exceeded value - - -	2	9	0
Percentage by which actual cost exceeded value -		490 %	

Amongst the causes for this absurdly low output were the variable and unsatisfactory machining, which was done under the time system; the undoubted indolence of the workmen and the poor quality of the supervision generally, which latter was responsible for the faulty machining on the one hand, and tolerated and therefore encouraged such idleness on the other.

No. 3. **Coppersmiths' Work.** The coppersmiths employed in a large shipyard were desirous of obtaining additional wages and to obtain these signified their willingness to take the work on a contract basis. A price was offered by them for carrying out the whole of the work involved in making and fitting the lubrication pipes for a large set of machinery. The work entailed the making of templates for the length and shape of the pipes, making the pipes, and fitting in the engine room. The price for which the men offered to do the work was held by them to be less than the cost of similar work done previously.

An investigation of the cost of work was already in hand, but, while it was desired to introduce payment by results, such an offer could not be accepted without adequate knowledge of the work involved; in any case the price appeared to be on the high side.

The leading hand, through whom the offer was made, and by whom it was understood later the estimate had been drawn up, was invited to collaborate in the building up of estimates for the different sections of the work. This was done, and after testing various doubtful points, agreement was reached on practically all details. The resultant total, however, was so different from the offer made and from his previous experience that the leading hand felt sure it would not be acceptable to the men; on the other hand, the firm's officials decided that the standard of cost for future work could not be set at that figure, and it was decided to adopt other methods.

With one section for which £5 were asked it was agreed the outside value was £2 8s., representing, in time, 48 hours instead of 100 hours.

Previous cost - - - - - - - - -	£260
Estimated value - - - - - - - -	100
Excess of cost over value - - - - - -	160
Percentage by which cost exceeded value - - -	160 %

It will be appreciated that when both the leading hand and the foreman of a section are satisfied with the existing output, any serious improvement is unlikely to follow. Fortunately, in this case, conviction followed as a result of the methods employed, and some increase of output was obtained, but the matter was not pursued by the management.

No. 4. **Tool-room Work.** Job—12 Milling Cutters, 2″ diameter 5½″ long; hole screwed in centre, 1″ diameter; and recessed each side to 1″ diameter. Operation—bore, face, screw and turn.

The work was done on an engine lathe—a good machine—suitable tools being provided. The time taken for the 12 cutters was 175 hours, and this was in keeping with the rate of output usually obtained. The outside time value of the work, even on the time system, was not more than 36 hours.

Total cost at 1/- per hour - - - - - -	£8	15	0
Outside value - - - - - - - - -	1	16	0
Efficiency of output - - - - - - -	20.6 %		
Cost exceeded outside value by - - - - -	386 %		

No. 5. Operation. Mill 16 spiral teeth in the Milling Cutters referred to in No. 4.

This work took 70 hours to do, but its time value was only 36 hours. The time rate paid was 9d. per hour. The comparison of the actual results with those possible are as shewn below.

Total cost at 9d. per hour - - - - - -	£2	12	6
Fair value - - - - - - - - - -	1	7	0
Efficiency of output - - - - - - -	51.4 %		
Fair cost exceeded by - - - - - - -	94.4 %		

At this period, because of the amount of work in hand, the whole of the tool makers were working overtime, involving the usual overtime allowances, although these are not included in the figures quoted. With a fair output, the overtime would have been unnecessary, more tools could have been made, expediting thereby the delivery of machinery which customers were urgently requiring.

The reason for the low output in the case of both operations was principally, indifferent supervision, of which the men took full advantage by taking things easy. The rate of output given was never questioned as to its amount; if the workmanship were such as would pass inspection no other criterion was applied. Men who were transferred to the tool-room from other departments

found it difficult to "hang their time out," but were almost forced to do so by the pressure of the old tool-room men.

EXAMPLES OF HIGH COST AND LOW OUTPUT UNDER THE PIECE-WORK SYSTEM

No. 6. **Machine Work.** Operation—Slotting naval gun carriage. Job rate 45/-. The basis of the job rate was the time taken on a trial batch and workmen aimed at earning at the rate of 1/- per hour. This job rate inferred 45 hours' work and this was the time taken, this rate of output being maintained for a number of years. A reasonable time for the work involved was 12 hours, and a job rate of 12/- would have been ample. At a later period the time taken was reduced to less than 8 hours.

In this connection it will be useful to shew the further effect of oncosts.

Piece-work rate of job - - - - - - -	£2	5	0
Value of job - - - - - - - - -	0	12	0
Piece-work rate exceeded value by - - - - -	1	13	0
Percentage by which cost exceeded value - -		275 %	
Percentage of possible output obtained - -		26.6 %	
Oncosts at 75 % on actual output - - - - -	1	13	9
Oncosts at 75 % on possible output - - -	0	9	0
Actual labour cost and oncost - - - - -	3	18	9
Fair labour cost and oncost - - - - - -	1	1	0
Excess actual cost over fair cost - - - - -	2	17	9

This is an example of the weakness of fixing piece-work rates in accordance with the time taken. The practice was for a batch of parts to be done as a trial batch and, in some cases, for a deduction to be made from the time taken, on the assumption that the man by getting used to the job would be able to effect an equivalent reduction; the rate was so fixed that, at this output, time and a third would be earned.

In this instance the reasons for the excessive times taken were slack supervision and absence of demand for better results; at a later period the same men gave a much larger rate of output for a similar standard of earnings.

No. 7. **Fitting Work.** Job—Field Gun Carriage. Operation—Fit trunnions to body. The job rate was 21/- and was arranged to allow earnings of 1/- per hour, which was the unwritten law of the shop. (The works concerned were in a different part of the country to that of No. 6.) The time value of the work to be done was 9 hours and the time taken in the course of months was reduced to this amount. Some assistance in this connection was obtained by a change from the piece-work system to the premium system, together with a guarantee that the job rates set under that system would not be cut, neither would there be any limit of earnings.

Job rate - - - - - - - -	£1 1 0
Time taken - - - - - - - -	21 hours
Time value - - - - - - - -	9 hours
Fair cost - - - - - - - -	£0 9 0
Excess cost of job - - - - - - -	133 %
Efficiency of output - - - - - -	43 %
Extra pay earned when 21 hours were taken -	26.3 %

The job rate was based on the time taken and there was reason to think that, in the early stages of the job, difficulties were encountered which had been gradually removed. There being no detailed record of the work covered by the job rate fixed, no attempt was made to effect an adjustment as the work was made easier while the fear of an undue reduction of the job rate kept the output down. The job rate should have been fixed on the basis of the value of the work entailed under normal conditions, the special difficulties existing treated as such, and made the subject of an independent allowance to be withdrawn as the difficulties were removed.

No. 8. **Automatic Screw Work.** The work consisted principally of screws, pins, washers, and nuts, brass and mild steel being the materials in most common use. Job rates were given in terms of money per hundred pieces, allowances being made therein for the various contingencies likely to arise in accordance with the nature of the material used. The opinion was held that the department was most efficiently run and that the resultant costs were such as would enable competition to be readily met.

The records of 10 jobs were examined with the following results:

Item.	Hourly Output			Piece-Work Efficiency. Cam Time Taken as 100%	
	as per Cam Time.	Expected.	Actual.	Expected.	Actual.
A	65	55	34	85	52.3
B	100	85	60	85	60.0
C	130	117	80	90	61.5
D	144	122	85	85	59.0
E	162	145	90	90	55.5
F	170	153	120	90	70.5
G	170	144	100	85	58.8
H	240	211	160	90	66.6
I	265	238	180	90	67.9
J	425	382	225	90	52.9

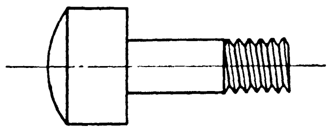
The weekly record of the first example (A) is shewn in the diagram on p. 20.

The reasons for this low output were somewhat difficult to ascertain. Apart from a distinct variation in shafting speed, the plant, the tool supply, and the amount of work available were all favour-

able to efficient output being given; but it was found that the division of the extra pay was unsatisfactorily made, the machine feeders being paid a larger share than were the machine-setters. Complaint had been made by the latter, but no redress being received, their output fell as shewn. In this case, the foreman was neither strong enough to control his men nor to convince his chief of the need for a change in the method of apportionment. His machines were allowed to be run using speeds and feeds that were less than those specified and known to be possible.

The cost of production of this department's work was as much as double those of competitors.

AUTOMATIC SCREW MACHINE OUTPUT



Material—Mild Steel. System—Piece-work.

Average hourly output per week for 26 weeks.

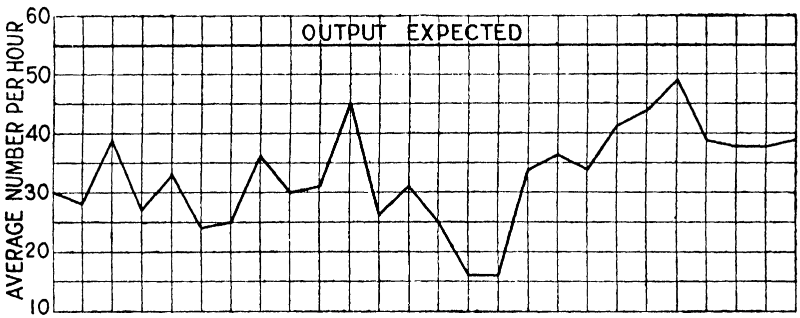


FIG. 2.

The low and varied rates of output were the result, principally, of dissatisfaction with the apportionment of the extra pay earned, between the machine-setters and the machine-feeders, the former being paid much the smaller proportion of the whole. Including oncosts, the weekly loss to the firm was nearly £2 per machine.

No. 9. **Capstan Work.** Job—Screwed Pin, pointed with knurled head. Operation—Turn, screw, point and part off. The job rate was .5 pence each, and the usual output was 10 per hour. The youth doing the job thought he could beat this and, in a trial, did 6 pins in 15 minutes, booking his week's work in at the rate of 15 per hour. This showed earnings of 7½ pence per hour which, on his hourly time rate of 4 pence, meant extra pay of 87.5 per cent., or 15 shillings and 9 pence per week of 54 hours. The next week the youth was given an increase of time rate of .5 pence per hour,

but his piece-work was stopped and he was expected to turn out the same amount of work. A fair job rate would have been .375 pence each and a reasonable output 18 pieces per hour. To ask for the same rate of output on time work as on piece-work was equivalent to a reduction of job rate from .5 pence to .3 pence each, the firm failing thereby to secure the further 20 per cent. increase which was possible. To the youth, the net result of his endeavour to earn more money was a demand for an increase of output of 50 per cent. in return for remuneration which was 40 per cent. lower than that first offered. This example shews that neither under the original piece-work rate, which was too high, nor under the altered conditions of payment was efficiency secured, either of output or cost.

EXAMPLES OF LOW OUTPUT AND HIGH COST UNDER THE PREMIUM SYSTEM

No. 10. **Machine Work.** Job—Aeroplane Spar Socket. Operation—Turn and bore. The arrangement existing was that men had promised to work at piece-work speed in return for which they were to be paid "time and a quarter." The Halsey-Weir system was used as the medium through which the extra money was to be paid, and the time taken on this job being 12 hours, the job rate was fixed at 18 hours, one half of the saving made being paid to the turner. There was an understanding also, that not more than "time and a quarter" would be paid, and this was one reason why the time taken on the earlier batches was maintained.

It was made clear, however, that this was not the case, and it was not long before the time taken for the operation was reduced to 2 hours 40 minutes. Although the output was much increased the cost remained high owing to the manner in which the job rate had been fixed.

Output and cost, actual and possible, compare as follows:

Cost when job was done in 12 hours - - - - -	12/6
Cost when job was done in 2 hours 40 minutes -	8/7
Value of job with equitable job rate - - - - -	3/-

Thus 25 per cent. extra wages were paid when the rate of output represented an efficiency of 22 per cent. and when the time wage cost alone was more than $3\frac{1}{3}$ times what it should have been.

The reasons for the low output originally were various: partly poor organization, waiting for work, and poor supply of tools, but to a much greater extent, slack supervision, of which the workmen took the fullest advantage.

No. 11. **Fitting Work.** Job—Aeroplane Undercarriage. Operation—Assemble undercarriage details. The time taken was 20 hours, and so that 25 per cent. extra earnings would be deemed to have been earned the job rate was fixed at 30 hours. At a later date the time taken was reduced to 8 hours, the working conditions

being similar. The operation could have been performed in 6 hours.

Comparison of the possibilities with the results actually attained are appended :

Cost when time taken was 20 hours - - -	£1 0 10
Cost when time taken was 8 hours - - -	0 15 10
Actual value of job, allowing equitable job rate of 9 hours - - - - - - - -	0 6 3
Percentage of increased output obtained - -	150 %

In this instance extra wages, equal to 25 per cent., were paid when the output showed an efficiency of 30 per cent. only, and the cost was $3\frac{1}{3}$ times what it should have been. The causes were faulty organization and bad supervision.

No. 12. **Sheet-Iron Work.** Operation—Cutting and forming socket plates.

While considerable quantities of socket plates were required, various designs were involved and the numbers called for, of any one type, were not sufficient to justify the provision of press tools ; consequently, the sockets were made by hand. The material used was of a light gauge, ranging from 2 millimetres in thickness downward.

The Halsey-Weir system was used, the job rates being based on time taken, to which was added 50 per cent. to provide the extra pay of 25 per cent.

	A.		B.		C.	
	Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.
Time taken - - - -	2	20	1	0	3	0
Fair time - - - -	0	40	0	10	1	30
Job rate fixed - - -	3	30	1	30	4	30
Fair job rate - - - -	1	0	0	15	2	15
Actual cost - - - -	2/$5\frac{1}{6}$		1/$0\frac{1}{2}$		3/$1\frac{1}{2}$	
Fair value - - - -	0/$8\frac{1}{3}$		0/2		1/$6\frac{3}{4}$	
Percentage by which actual cost exceeded fair value -	250 %		500 %		100 %	

At a later date each of the jobs mentioned was done in the " fair " time suggested, and in some instances in less time.

The reasons for the unsatisfactory output and cost are somewhat difficult to define. There was some evidence that the supply of work at one time was intermittent and that some of the times taken were affected thereby, an argument that temporary conditions should not be allowed to affect the job rates themselves. On the other hand, the rate of output given was accepted without inquiry or comment and, after the job rates had been fixed, the

fear of a reduction, if more than 25 per cent. extra pay were made, prevented an increase in output.

No. 13. **Assembly Work.** Job—Gear Box. Operation—Assemble all parts and adjust.

The job rate was estimated, originally, and was based on 40 hours' work, the rate fixed being 60 hours. Owing to the difficulties experienced this was raised to 75 hours, while allowances were made as required for faulty machining, of which there was a considerable amount. The time taken, however, went as high as 400 hours, but on this being reduced to about 150 hours, instructions were given by the management of the works that the job rate was to be raised to this amount. Actually this instruction was not strictly observed the job rate being raised to 130 hours only. This did not satisfy the men concerned and no further improvement in output took place. Other methods were adopted, a change of workmen was made and the time taken was at once reduced, one man, on his third box, taking 47 hours, he having in this time to wait for some of the parts, for which no allowance had been made.

The real trouble was there were too many men employed for the work available; for this, the increase of the job rate was no remedy, neither was it a question of more effort being required.

The actual cost compared with the value of the operation was as follows:

Estimated value of job - - - - - -	£2	0	0
Actual cost of job when completed in 150 hours -	5	12	6
Actual cost when job rate raised to 130 hours and time taken reduced to 47 hours - - - (Halsey-Weir system.)	3	6	4½
Percentage by which cost exceeded value when 47 hours were taken - - - - - - - -	65.9 %		

Even with the reducing factor of the Halsey-Weir system it was impossible for the actual cost to have been brought down to the fair cost, not even if the job could have been done in 1 hour; the cost would then have been £2 9s. 1½d., or 22.8 per cent. more than the value.

COMPARISON OF OUTPUT OBTAINED EITHER UNDER THE TIME SYSTEM OR UNDER PAYMENT BY RESULTS WHEN JOB RATES WERE BASED ON TIME TAKEN, AND UNDER PAYMENT BY RESULTS WHEN JOB RATES WERE BASED ON ESTIMATED TIME

The examples given under this head are perhaps the most important of all inasmuch as by them practical illustration is given of the feasibility of fixing job rates without being dependent upon past records, or without having to wait for particulars of the time taken in the case of new jobs. Several processes are dealt with which go to indicate the general practicability of the method.

In one works the time system had been in operation, and with the object of increasing the output the Halsey-Weir system was introduced. The management had no definite ideas as to how far from efficiency the output previously obtained actually was, but there was a feeling that a bigger output was possible, and, provided this was ensured with less cost and without abnormally large earnings, everyone was likely to be satisfied. The change from one system to the other was not welcomed by the workers, and, on the other hand, the supervision staff who had for long years been used to a certain rate of output were not disposed either to consider that a large increase was possible or to give the movement their whole-hearted support. Some interesting incidents took place, and in some cases it was a question of demonstrating to the staff as well as to the workers that that which had been estimated as possible could really be done.

The experience is by no means an isolated one, nor is it confined necessarily to the lower ranks of a works staff. The author has known of cases where the worker's complaints regarding job rates have been taken up to the directors of the company as examples of the impossible tasks which were being set by the men they had appointed, after which it has been demonstrated that those same job rates represented not possibility only but reasonable possibility.

One simple example of this attitude in connection with the turning of Admiralty test pieces is worthy of mention. The time taken on this operation had averaged 2 hours each, but the time estimated and on which the job rate was based was 50 minutes, the job rate itself being 1¼ hours. Complaint was made to the foreman, who, after seeing his head foreman and works manager, and stating the operation could not be done in less than 1½ hours, was referred to the general manager. Fortunately the latter suspended judgment and the operation was tried in another shop, when batches were done in times averaging as low as 45 minutes each, or in one half the time reported to the general manager as being possible.

The following example is typical of the increased output and decreased cost obtained by the adoption of a system of payment by results when job rates are based on estimated time instead of time taken; at the same time the job rate given was probably 9 hours more than was really justified by the amount of work to be done even when the small quantity was taken into consideration.

No. 14. **Machine Work.** Job—Engine Fly-wheel. Material—cast-iron. Operation—Turn, bore, and face, and polish rim.

The engines for which fly-wheels of this size were required were usually made against individual contracts, the manufacture, therefore, being of a jobbing character, one set of parts only being handled at a time. The average time taken on fly-wheels of this kind and size was 40 hours, and in view of this what was really a high job rate was given, viz. 25 hours, in fact the turner refused to accept any less. The first one done under this job rate came out in 13

hours, although this was improved upon later. The improved output and cost compare as follows :

Cost under time system, 40 hours at 1/- per hour -	£2 0 0
Cost under premium system, 13 hours plus one half of time saved ; 13 + 6 = 19 hours - - -	0 19 0
Increased output - - - - - - - -	207 %
Workman's increased earnings - - - -	46 %
Reduced labour cost - - - - - -	52.5 %

No. 15. **Machine Work.** Job—Steel Flanges. Operation—Turn, face and bore.

Large quantities of flanges of different sizes were used and the time taken on the 6 inch size, by men and apprentices, was, on an average, two hours each. Where the apprentices were concerned there had been some kind of bonus given up to a maximum of time and a half if they turned out " a lot of work." This was held to have been achieved by doing as much work as the journeymen did, so the question was one of starting off from what really, was a " time and a half time rate."

The work was carefully estimated, by which it was shewn that there was 47 minutes' work. The apprentices were told that if they would turn out flanges at this rate they would be paid double their time rate of wages, although their other " output bonus " would be stopped. This meant a job rate of 1 hour 10 minutes per flange for journeymen and 2 hours 20 minutes for apprentices in their first year, as these were. The incongruity of first year apprentices and fully rated journeymen doing the same work in this manner is appreciated, but that is a not uncommon feature in many workshops.

The results, as will be noticed, were extremely good :

	Hr.	Min.
Time taken under time system and paid for - -	2	0
Time taken under Halsey-Weir system - - -	0	47
Time paid for under Halsey-Weir system—Men -		58.5
Time paid for under Halsey-Weir system—Apprentices - - - - - - - - -	1	33
Increased output - - - - - - - -		155 %
Cost at 1/- per hour. Time system - - -		2/-
Cost at 1/- per hour. Halsey-Weir system - -		11.7d.
Decrease in cost - - - - - - - -		51.2 %

The reduction in cost with the apprentices' work was in similar proportion, but their low time rates went to depreciate the importance of the changes effected. There is no doubt that the reason for the low output was poor supervision.

In another works the piece-work system had been in use but had been discarded for the Rowan system ; the position met with was somewhat different. The piece-work system had been loosely administered, job rates being based on time taken, and carrying payment of time and a third. Quite a comfortable pace had been

set and competition not being keen, its influence had hardly been felt. The job rates had been fixed by the supervision staff and it was not unnatural that they looked upon any material increase of output as being likely to reflect unsatisfactorily upon them and upon their ideas of what operations were worth as shewn by the job rates fixed by them. This made the work somewhat difficult, and examples No. 16 and 17 reflect this difficulty.

No. 16. **Machine Work.** Job—Central Pivot. Material—Forged mild steel. Operation—Rough bore 2⅛ inch hole.

The job, weighing approximately five cwt., was 30 inches long and was being handled in an old machine on which the fastest speeds which could be safely obtained were too slow. The boring was being done with a plain "D" bit, the hole being opened up in a previous operation to give the bit a true start. The rate at which boring of this kind and size had been done previously was 9 inches per hour and, for a job of this length and size, 4 hours were taken, this performance carrying with it earnings of time and a third. This at 7½ pence per hour, the time rate paid, plus one third, meant a job rate of 3s. 4d.

The estimated time on which the premium job rate was based was 2 hours 20 minutes, and for this machine this called for a penetration of 18 inches per hour. This was said to be impossible, the time taken being as high sometimes as 4½ hours. The feed and speed were experimented with on one pivot after which the rate of penetration specified was obtained, and with an additional "D" bit provided, so that time would not be lost waiting for re-hardening and so on, the time taken was reduced to 2 hours, which left 20 minutes for contingencies and still ensured "time and a third."

Cost under piece-work system - - - -	3/4
Cost under Rowan system - - - - - -	1/11.3
Increased output - - - - - - - - -	71 %
Workman's earnings—time and a third - - -	no change.
Reduced labour cost - - - - - - -	41.6 %

Literally speaking, this alteration to the system in use and the giving of new job rates could be held to constitute what was really a reduction in job rates. So far as the workmen were concerned, their rate of output had been accepted as satisfactory, otherwise they would not have been paid a third over their time rate of wages. In the case cited, however, a point of some interest arises. The increased output secured was not the result of additional effort on the part of the workman but was obtained principally by the more efficient use of the machine and tools provided, and these were within his power to secure. The additional effort required from him was to put extra pieces into the machine at the rate of rather less than two more per day. From this standpoint it could be argued that the change in the rate under the two systems was justified, inasmuch as in each case the rate could be said to have been proved by the time taken.

No. 17. **Machine Work.** Job—Side bars for 4″ Gun Mounting. Material—Forged steel. Operation—Plane all faces.

This piece was entirely new in design and no previous records were available. A job rate of 13½ hours had been fixed under the Rowan system, which meant the job should be done in 9 hours. The planer considered the job was worth double, and this was in accordance with the usual rate of working. The time taken on several batches was 105 hours for 6 or 17½ hours each. The estimate was examined but no serious error could be detected and attention was given to the methods being used. While some slight improvements were made these were almost negligible and went to improve the quality of the work rather than to improve the facilities for output.

The men knew they had the backing of the foremen's opinion in this case and no improvement was obtained until a batch had been done under observation, in accordance with the estimate taken out. The time per batch was reduced at once to 51 hours for 6, or 8½ hours each, and this became the average time. Had the time taken by the men been used as a basis for job rates as had been previously the practice the job rate each would have been 17/6, giving a comparison as follows:

Hours taken before investigation - - - - -	17½
Hours taken after investigation - - - - -	8½
Cost before investigation - - - - - -	17/6
Cost after investigation - - - - - - -	11/7½
Increased output - - - - - - - - -	105 %
Decreased cost - - - - - - - - -	33·5 %

The extra pay earned was similar to that which would have been secured had the job rate been fixed as formerly, but the latter would have been higher and the output lower.

No. 18. **Fitting Shop Work.** Job—Water-tight hatch and cover 2′ 6″ × 2′ 6″. Operation—Chip radii on coaming, assemble cover to coaming, mark off, cut and fit strips, mark off for drilling, tap, assemble temporary rubber, assemble and adjust rubber complete.

Hatches of this type and size usually took 48 hours or more on the time system. Under the Halsey-Weir system it was estimated the work should be done in 27 hours; actually they were done in less than 25 hours.

Cost under the time system - - - - - -	£2	8	0
Cost under the Halsey-Weir system with job rate of 45 hours - - - - - - - - -	1	15	0
Increased output - - - - - - - - -	92 %		
Increased rate of earning - - - - - -	40 %		
Decreased cost - - - - - - - - -	27 %		

Low output here was induced by lack of close supervision. In this particular shop, if jobs were not ready, men were told to "go and hide themselves."

No. 19. **Marking-off.** It is by no means an uncommon experience to find that around "the slabs" work accumulates at a faster rate than it is disposed of, and that periodical bursts of overtime are necessary to wipe such accumulations off. The situation is made worse when payment by results is started, because the greater volume of work being handled as a consequence necessitates either quicker handling by the markers-off or more slabs and more men to do the work. In several instances the results of the operation of payment by results with markers-off has been that such accumulations have been wiped out, while the increased amount of work going through the shops has been handled without any increase in the number of men or slabs provided.

The records for the time taken for the marking-off of certain pieces which had been done under both the time system and the Halsey-Weir system were collected and examined, and for ten different parts covering 891 pieces the time taken and the cost incurred shewed up as follows :

Hours taken under the time system - -	1396
Hours taken under the Halsey-Weir system - -	579
Percentage of increased output - - - - -	141 %
Approximate percentage of increased earnings -	35 %
Approximate percentage of reduced labour cost -	44 %

The reason for low output, to some extent, was faulty organization, but the foreman had been contending with this for some time and the results obtained were very much helped by his attitude and influence ; in fact without him the output would have been lower and the cost much higher.

No. 20. **Tool-room Work.** The output of tool-rooms under the time system is generally low, and in several tool-rooms where payment by results has been introduced the output has been more than doubled, the quality of the workmanship not being affected. Because of its varying character and the difficulties which accompany it, tool-room work is somewhat difficult to supervise as regards output, and some form of production statistics or payment by results is essential if anything like a reasonably satisfactory output is to be obtained.

Because of the varied character of the work, absolute comparisons are somewhat difficult to obtain, and to a great extent supervisionary control depends upon general knowledge as to the amount of work being turned out. In one instance a number of press tools were required, of the same design, but whose dimensions differed slightly. Several of these done under the time system took from 39 to 45 hours each, while those done under the Halsey-Weir premium system, with job rates varying from 25 to 40 hours each, were completed in times ranging from 15 to 25 hours each.

Similar have been the experiences with template, gauge, and jig work. On plate gauges for pinion and worm-wheel teeth, it was quite common to find the time taken under the time system was

more than double what the estimate shewed, and more than 12 months have been taken before the job rates given in such cases have been "made to pay."

One such case was that of jig boring, for which the lathe was being used. The recognized rate was one hole per day, irrespective of size, and had it not been for the fact that the estimator concerned with that department had actually done similar work in another tool-room in from 1¼ hours to 3 hours per hole according to size and the number of "points" from which accuracy was required, it is doubtful if he would have been able to have stood against the consensus of opinion of workmen, foremen, and the departmental manager, that the job rates fixed ranging from 2¼ hours to 5 hours per hole were ridiculous.

The weakness with tool-room work is that its natural difficulties are so readily treated as insuperable, so far as applying a measure of output is concerned, that rate of output is just left to evolve, and it does evolve and at a very slow pace.

No. 21. **Carpenters' Work.** Job—Shop offices. Operation—Make and erect.

Shop offices were made to one design, there being slight differences in size. Under the time system the time taken varied from 350 to 400 hours each. Immediately prior to the introduction of the Halsey-Weir premium system one of these offices was completed in 377½ hours. Shortly after another office, slightly larger but otherwise the same, was made and erected under the premium system in 221 hours, the job rate given being 340 hours.

Output and cost compare thus:

Cost under time system - - - - -	£14 3 1½
Cost under premium system, including extra work	10 10 4½
Saving shewn - - - - - - - - -	3 12 9
Increased output - - - - - - - -	70 %
Increase in carpenters' earnings - - - -	26.7 %
Decrease in cost - - - - - - - -	25.6 %

No. 22. **Electrical Work.** Operation—Making clips for cables.

Under the time system 5 men were required to supply the demand. As a result of the increased output obtained under the Halsey-Weir premium system 2 men were able to meet the requirements, which were considerably greater owing to the increased output obtained from the electricians generally, the result of the operation of the same system. Over a period of several months, clips, which on the basis of previous output would have taken 5,346 hours to produce, were turned out in 2,160 hours, an increase in output of 147 per cent.

Similarly, where armature winding and repairs were concerned, 3 men, working under the premium system, were able to handle all the repairs required and on a plant whose size was increasing, whereas 5 men under the time system were employed.

In the two sections, the result of the operation of the different

systems compares as follows, the figures being quoted as affecting one week only:

Number of men required under the time system -	10
Number of men required under Halsey-Weir system - - - - - - - - -	5
Approximate increased earnings of workmen - -	$33\frac{1}{3}$%
Approximate saving in cost per week at average rate of 1/- per hour - - - - - - -	£7 17 0
Percentage increased output - - - -	100 %

In the case of the clip makers this increase of output enabled the manufacture of same to be continued in that works; otherwise it would have been necessary to purchase outside, which could have been done at a lower price.

No. 23. **Aeroplane Work.** Operation—Covering with fabric. This work had been done entirely under the time system, fully skilled tailors having been employed to carry out the work. The volume of output obtained was most unsatisfactory and girls were introduced to do the same work. The system of working was changed and there was evidence justifying the impression that the man in charge of the work was against any increase in output being shewn. The records of the output given by the men were not well kept, but it was known that more aeroplanes were being covered by a given number of girls than had been done by a similar number of men.

With a view to increasing the output still further the Halsey-Weir system was introduced, and records taken haphazard shewed the following comparisons.

The operation in each case was to cover the part mentioned with fabric.

Quantity.	Name of Part.	Hours Taken.		Percentage Increased Output.
		Time System.	Premium System.	
66	Upper plane - - -	1584	1005	57
75	Lower plane - - -	1800	1175	53
35	Tail plane - - -	608	$365\frac{1}{2}$	66
15	Centre plane - - -	120	$67\frac{1}{2}$	78
162	Flaps - - -	1620	615	163
107	Elevators - - -	856	413	107
55	Rudders - - -	330	236	40
	Total -	6918	3878	78

Leaving out the reduction in cost following the displacement of men by girl labour, the saving in money shewn above is equal to nearly 30 per cent., or, at a time rate of 1/- per hour, allowing for earnings of $33\frac{1}{3}$ per cent. on time wages, a sum of £87 7s.; in addition to this there was a considerable saving in oncosts.

The reason for the low output given by the men was due in part to the fact that when the work was started up it was quite new in its character, and the demand being a gradually growing one, new and, therefore, slow men were being taken on almost week by week. No demand was made for a larger output and none was given, while the attitude of the charge hand was of a restrictive character; consequently the output given was on the basis of "new jobs."

No. 24. **Moulding and Coremaking.** Of a somewhat interesting character are some of the records of moulding, and these lend colour to the contention that, in some industries, at any rate, efficient output cannot be ensured without payment by results. For long years the moulders, as a body, have objected to all systems of payment by results, but that has been the official attitude, and payment by results has been accepted by some moulders in a foundry and rejected by others. Under such conditions the difference in output from the various men could not be held to be due to weakness of organization, although inefficient supervision could have been a contributory cause to low output. With this reservation the difference in output can reasonably be held to indicate the true difference between the values of the two methods of payment, and the fact was recognized by the men themselves, who watched their fellows and spotted them because of the "way they worked"; this, of course, had a deterrent effect on those men who were working under payment by results and tended to keep the output down. The examples given have reference to more than one foundry.

Job.	Quantity.	Time Taken in Hours. Method of Payment.			Percentage Increase.
		Total.	Time.	Results.	
Gear bracket	20	260	13	—	—
	10	90	—	9	44.4
Pump body	21	105	5	—	—
	15	56¼	—	3¾	33.3
Gear case	40	320	8	—	—
	10	45	—	4½	77.7
Bevel wheel	6	36	6	—	—
	4	8	—	2	200.0
Bearings	20	30	1½	—	—
	20	10	—	½	200.0
Socket	40	220	5½	—	—
	24	90	—	3¾	46.6

The average increase of output shewn by the foregoing figures is equal to 59 per cent., while the reduction in cost is 16.3 per cent. From the records of upwards of 60 jobs compared, the increased output varied from 20 per cent. to 400 per cent., the increased earnings averaged 35 per cent., and the decreased cost represented a saving of approximately £20 per week.

Ship Fitting. It would probably be found, if inquiry and comparison were made, that the amount of work done by men engaged on any kind of ship fitting, when such work was carried out on the ship itself, would be much less, value for value, than that experienced in almost any other branch of the industry, and it is probably true that, in this respect, ship work represents the most inefficient branch of engineering known as regards cost of production.

Such a statement by itself, however, is not sufficient and casts a reflection which is but partly justified. From the standpoint of efficiency of output and of supervision ship fitting presents one of the most difficult problems that can be met with. Actually a ship is not unlike a house with many rooms but provided with few passages. All traffic between certain rooms must pass from room to room in both directions. The urgency of the work is usually such that men of several trades are working in the different "rooms" at the same time, unavoidably causing some interference with each other. Added to this the traffic from room to room is bound to cause further interference, more particularly when men are working near doorways or when the "rooms" are small or narrow. Thus in any case, output is not a question of time and effort only but rather time and effort and an ever-present interference handicap, and under the conditions mentioned an accurate measure of output and the obtainment of truly efficient output are matters of some difficulty.

From the standpoint of efficient supervision, the conditions present an equally difficult problem. The men are bound to be scattered about in the different compartments, and for supervision to be effective, the only solution would be a foreman in each, but this is not practicable, if only from the point of view of cost. Supervision can only be casual, and this is rendered less effective by the use of signals made by workmen on the approach of any particular official.

The negative influence of the time system on output is probably more disastrously felt in ship fitting than in any other branch of the industry, and this, together with the unavoidable difficulties of the work and of supervision, go far to explain why output is so low.

The psychological effect is to induce slackness amongst staff as well as workmen, and there is reason to fear that this tendency has not been sufficiently realized, that the problem has not always been tackled as well as it might have been, and that better results were possible if they had been seriously sought.

Many of the examples quoted as to the difference in the volume of output under systems of time and of payment by results have reference to ship fitting, and the reason for such large differences can be correctly appreciated only when the general conditions under which the work has been done are known. It is safe to say that in no branch of the industry is payment by results likely to be attended with greater success than in ship fitting. So much more can be accomplished when the will to do so is in existence;

nowhere can the spirit of mutual accommodation remove more difficulties.

No. 25. Job—Mechan water-tight Door. Operation—Fit and bush 10 handles and hang door.

This operation covered all the work required to fit and hang 10-handled Mechan doors and the time taken varied from 108 to 150 hours. It would be more correct to say 54 to 75 hours, but two fitters were employed and the time was booked accordingly. The second fitter was really unnecessary, occasional service from a labourer being all that was required. The operation was one in which a considerable amount of interference was likely to be experienced, but, bearing this in mind, it was estimated the work involved justified a job rate of 40 hours, although in view of the previous rate of output obtained 45 hours were given. The second fitter having been set on the job by the foreman, this had to be taken into account, the result being the legitimate job rate had to be doubled. If this had not been done, little opportunity for earning extra pay would have been presented, and no increased output may have resulted. The output, however, was soon increased, and it was not long before the doors were being hung in 22½ hours per man or 45 hours total. In the course of time the second man disappeared, two men preferring to take on two doors at a time or one each, after which the job was recognized, as it really was, a legitimate one-man job. Doors have been hung by one man in as low a time as 19½ hours; the average is taken as 25 hours.

The improvements shewn in both output and cost are considerable, but the cost will always reflect the folly of employing two men to do one man's work. It could be contended that the removal of the second man justified a revision of the job rate, but such an excuse for adjustment is exceedingly thin. Job rates, theoretically, should be based on the amount of work to be done, not on the manner in which jobs are manned. It may be that owing to circumstances, a firm may decide on a policy of compromise; when such is the case the manning of the job would have to be considered and the job rates will be affected accordingly. One of the direct results of the operation of the system in use and of the influence of the job rate was the removal of the second fitter, such removal, in cutting out what was largely idle time, providing opportunities for still further increased earnings. Therefore, what supervision should have done was left to be accomplished through payment by results, and this is one of the results for which this particular firm intimated its willingness to pay, without realizing, probably, just how serious was the commitment made.

The comparison is of special interest, because the increased output is not really as great as the figure would suggest, and would be more fairly shewn partly as increased output and partly as the result of the better use of labour.

Cost under time system	£5 8 0
Cost under Halsey-Weir system (2 fitters)	3 7 6
Cost under Halsey-Weir system (1 fitter)	2 17 6
Estimated cost as per job rate of 45 hours	1 16 0
Greatest actual saving	2 10 6
Hours taken on time system (2 fitters)	108
Hours taken on Halsey-Weir system (2 fitters)	45
Increased output	140 %
Average hours taken on the Halsey-Weir system (1 fitter)	25
Increased output brought about by harder work and better use of labour	332 %
Percentage of increased earnings	130 %
Percentage of decreased cost	46.7 %
Percentage by which lowest actual cost exceeded estimated fair cost	59.7 %

The fact that, even though the cost was reduced by 46.7 per cent., it was still 59.7 per cent. more than the value of the work justified, will be appreciated, and it should be remembered that conditions of this nature must ever accompany the use of payment by results in a similar wrong manner.

No. 26. Job—Keel block for submarine. Operation—Chip, fit to shell, joint, tap, and rivet.

The time taken for carrying out this operation varied from 78 to 108 hours. Two fitters were employed and could be profitably employed, but the practice on other jobs being for the second fitter to be a supernumerary, one man only at a time to work, excepting it was really a two-handed job, reacted in this case, and one or other of the men was generally a looker-on.

The Halsey-Weir system had been introduced and a job rate of 39 hours was given, the operation being done subsequently in 19½ hours.

Cost under time system	£3 18 0
Cost under Halsey-Weir system	1 9 3
Increased output	300 %
Increased earnings	50 %
Decreased labour cost	62.5 %

While it is not desired to depreciate the workman's efforts and willingness to improve the output, it is necessary to point out that the increase of output—300 per cent.—was not obtained because four times the normal effort was put forth, but to a considerable degree was due to the elimination of the idle time of the second man. Two men could work without inconveniencing each other, but, as so often happens in works, if one set of men enjoy what appears to be a concession, their fellows seek the same privilege; in this case the second man always took it easy, each being "second" man in turns—both at times.

No. 27. **Electricians' Work on Board Ship.** Operation—Mark off, paint, and dab positions for clips, lights, switches, fans, etc.

On a similar vessel, for the same customer, the equivalent work was done under the time system in 298 hours, by one man and one helper. It was estimated that the work should be done in 80 hours, requiring a job rate of 120 hours, and it was considered that no helper was necessary. The electrician concerned contended, however, not without reason, that to do the job in this time, in view of that previously taken and also of the fact that he was to do without the services of the helper, insufficient time was allowed, and that to do the work in the time estimated justified a return of more than time and a quarter, the amount on which the job rates were then based. The weakness of the position was appreciated and the job rate was raised to 155 hours, after which the operation was completed in 75 hours. While the saving shewn more than compensated for the extra hours allowed, it does not alter the fact that because of the previous low output and practice, the job rate was permanently made 35 hours greater than the amount of work justified. The incidence of the addition will be noted.

Cost under the time system at average rate of 10d. per hour for electrician and helper—298 hours	£12 8 4
Cost under the Halsey-Weir premium system, electrician only, 75 hours time wages plus 40 hours extra pay—115 hours at 1/- per hour	5 15 0
Increased output on the basis of hours booked -	297 %
Workman's increased rate of earnings - - -	53·3 %
Reduced labour cost - - - - - - -	53·6 %

If a fair rate of output had been obtained previously a job rate of 120 hours would have satisfied the workman, and the subsequent cost would have been £4 17s. 6d. As it stood, in spite of the considerable saving shewn, the actual cost compared with that estimated and reflected in the job rate was 18 per cent. greater than the work justified.

No. 28. **Sheet-Iron Work.** Job—Ventilation Trunk. Lift template, make complete and fit on ship.

This example is particularly interesting, inasmuch as three periods are covered—when the time system, the piece-work system, and the time system again were in operation. On the time system, prior to the introduction of piece-work, the time taken was 30 hours. Under the piece-work system, with a piece-work job rate of 22 shillings and 6 pence, the work was done in 11½ hours, but on reverting to the time system, owing to the objections of the sheet-iron workers to the continuation of payment by results, the time taken was increased to 21 hours.

This is not an unusual experience and the instance here given may be taken as being typical. In similar circumstances, in another trade, the output given under the premium system in 721 hours

took 1426 hours to do on the reversion to the time system, an increase in the time taken of 97 per cent, barely half the work done.

These are typical of the cases which go to convict workmen of malingering, and the fear is, that the decreased output as shewn is the result of a policy laid down, either by the men of the workshop itself, or by their trade society representatives. In either case, but particularly in the latter, the situation is an exceedingly difficult one to handle, and is, perhaps, one of the most sinister signs of faulty leadership possible, when viewed from the standpoint of the well-being of the industry. Compared, the results on this job shew the following percentages:

Hours taken on time, before piece-work introduced - - - - - - - - -	30
Hours taken on the piece-work system- - -	11½
Hours taken on time after piece-work abolished -	21
Increased output under piece-work system - -	160 %
Decreased output after piece-work system abolished	54.7 %
Cost when 30 hours each were taken by man and helper - - - - - - - - -	£2 3 9
Cost when 11½ hours each were taken by man and helper - - - - - - - - -	1 2 6
Cost when 21 hours each were taken by man and helper - - - - - - - - -	1 10 7½
Increased earnings under piece-work - - -	33 %

The various examples given cover a sufficiently wide field to indicate the possible scope for improvement, and the fact that many of the results achieved were due as much to the improvement of organization or to the counterbalancing effect of the job rates on faulty supervision, as they were to the expenditure of increased energy by workers is a matter of considerable moment.

It may be thought that the greatest weakness lies with workmen and supervision staff; superficially this may be so, but, after all, management has some duties and responsibilities in this connection. There is an old saying that " he who pays the piper calls the tune." The tune played in any works is called by the man in control, and whether he be manager or director, if the tune called be one of slow time, the responsibility must lie accordingly.

In some works where payment by results is given undue prominence it is considered of more importance to give job rates than to obtain efficiency. In one day, two complaints were made by one manager that on two machines no job rates had been fixed. One was an automatic screw machine, set up to produce the job in 1 minute 47 seconds. A fair time was 60 seconds, but the manager's instruction was to base the time on the running of the machine and " then let the man put his back into it." Interpreted, this meant let the machine be set so that the time taken is 78 per cent. too much, to that time add the requisite amount to enable 33.3 per cent. extra pay to be made, and, by so doing, ensure high earnings, high

RINGS, LOCKING CASES.

Operation—Turning. Estimated time—25 minutes.

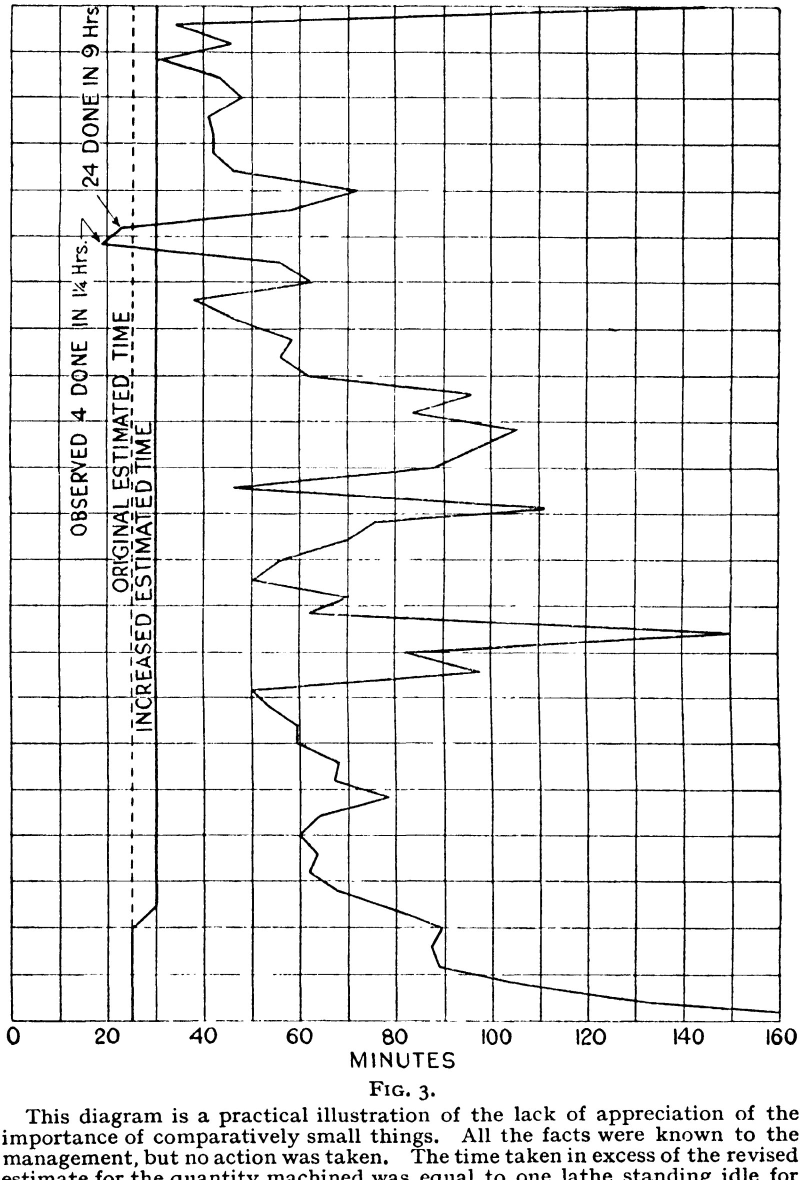


FIG. 3.

This diagram is a practical illustration of the lack of appreciation of the importance of comparatively small things. All the facts were known to the management, but no action was taken. The time taken in excess of the revised estimate for the quantity machined was equal to one lathe standing idle for 1 year 8½ months, although, in this period, more lathes were purchased in order that the output required could be obtained.

costs, and probably low output, and, what is of more importance, a certain need for a future reduction of job rate.

The second case was that of an automatic gear-cutting machine from which bevel pinions were being turned out in an average time of 1 hour each against an estimate of 25 minutes; the actual times varied up to 1 hour 30 minutes. Again the remedy was to give a job rate so that "the man will have some encouragement to get over the trouble." Again, if this manager's instructions had been carried out, the workman would have been paid over and over again, by virtue of his enhanced job rate, for getting his machine in order and correctly set; supervision, knowledge, and a little assistance were required—then job rates.

In another works a large number of gun-metal castings required turning. The estimated time was 20 minutes each, raised later to 25 minutes for the purpose of encouraging output. For 12 months the output from 4 lathes was as seen in the diagram on page 37, Fig. 3, although numbers had been done under observation in as low a time as 15 minutes each. The matter was known to the senior officials of the works, but no attempt was made to obtain the output which had been proved to be possible.

Efficient cost is the result of a combination of knowledge, control, the use of right methods, a satisfactory supply of work, and ability and willingness of workers to produce, and, where payment by results is in use, of job rates in which all these factors are reflected.

CHAPTER III

METHODS OF REMUNERATION. THEIR INFLUENCE ON OUTPUT AND WORKMANSHIP

THE remuneration of labour might be said to embrace almost the whole of the industrial problem; true, there are questions outside that of remuneration, but many of these have had their sources in the discontent which has centred therein. That this is the case is by no means illogical, in fact any other result would be surprising, and, in the broad sense, the development of the question, so rapid during recent years, is really a good sign. Activity is a sign of life, while the pursuit of a definite aim is an indication of intelligence, and the keener these indications are, the more intelligence is to be presumed as being in evidence, and in so far as that intelligence is wisely guided and used will its value be felt in a production sense.

The actual relationship between an employer and his employee is one for which a definition would be of interest. Is it a purely business contract, or is it one of trust? It would appear to be neither the one nor the other. Fundamentally the basis is that of bargaining, the employer endeavouring to get his work done for the lowest rate of remuneration possible; alternatively, and seeing there are two sides to a bargain, the employee seeks to obtain the biggest rate of wages he can, but whatever is the agreement which may be reached, it will be influenced by the state of trade—economic conditions. Rate of wages, however, is but one factor, and cost of production, the vital consideration, involves rate of output. Then an employee who has been constrained, perhaps, to work for a lower rate than he desired retains the power either to counteract or support the agreement reached by giving in return a large or small measure of output. What is humanly to be expected from an agreement of this kind, where one of the vital factors only is fixed, and this oft-times the result of a compromise rather than of genuine agreement, and what steps are taken to ensure that a reasonable return is made for the money expended in wages?

Generally speaking, wages represent an agreed rate of remuneration for services rendered. Such services may be specified as to their nature without particular reference to the number of hours to be worked—although this practice is fast dying out—or to the amount of work to be performed, or to the quality of such work;

domestic service is probably one of the best examples of this method. Again, the nature of the services required may be definitely specified and the hours of labour may be laid down, but otherwise no reference may be made to the amount or quality of the work done. Still further, the nature of the services required, the hours to be worked, the amount and quality of the work to be done may all be specified and be reflected in the amount of remuneration or wages to be paid.

In the broad sense it will be found that the methods whereby the services rendered are remunerated fall under two heads:

1. Made independently of the extent or quality of the service.
2. Made in direct proportion to the extent and quality of the service.

In the engineering trades there is a modification to the second method, there being a guaranteed minimum rate of remuneration, independent of the quality or the amount of work done. There are different applications of each of these methods, but those only which are of direct interest in engineering manufacture, to which this book is confined, will be dealt with.

Where remuneration is made independently of the extent or quality of service, the method of payment used is known as the time system. The time system is to be found in many industries, and under it, usually, rates of wages and hours of labour are specified. The rate may be stated in terms of so much money per hour or per week of a given number of hours, but this is a matter of convenience or local practice rather than of principle. Payment is made strictly in accordance with the number of hours worked, hours worked signifying nothing more than hours attended. Thus if no work had actually been done or if the time expended had resulted in the spoiling of all the material worked upon, the rate of remuneration agreed upon would be due and in accordance with the hours so "worked." Alternatively, a worker whose skill and energy enabled him to produce at a much greater rate than his fellow worker and that satisfactorily, would receive but the same rate of pay as would the less efficient individual.

It is appreciated that, with one school of thought, this is considered to embody the right principle; it is contended by that school that wages should have no relation to output; that the means of subsistence should be assured to everyone independently of the ability to produce.

From an idealistic standpoint this attitude is without doubt a worthy one, and, as an object to be striven for, is deserving of every effort; but one difficulty at the present time appears to be that the imperfections of human nature are still so pronounced, and it is so difficult to distinguish the lack of ability from the absence of desire to produce, that the practical realization of this ideal appears to be impossible, and to attempt it, immediately, would be but to exchange certain unsatisfactory features which are known for others the extent of the influence of which would be unknown.

While, it may be stated, the principle is not entirely unrecognized, the question can only be dealt with here in accordance with present-day facts and conditions, and the treatment, therefore, will not imply any political faith or prejudice.

Reverting to the more direct discussion of the time system, there are some occupations where no other system would appear to be applicable, where the duties involved are so variable or of so intermittent a character that, so far as individual output is concerned, little or no influence can be exerted; for example—an engine driver, a lift attendant, a store counter attendant or a crane driver. This is not to say these people have no influence on output; this they undoubtedly can have, but such influence as can be exerted will be of an indirect character.

In a large number of instances, however, where manufacture is concerned, the existence of the time system is, usually, a matter of choice or agreement rather than of the exigencies of manufacture. At the same time considerably diverse views are to be found regarding this phase of the question, and these are worthy of careful examination; in fact, in the eyes of some people, both employers and workers, the whole case against the employment of any other method of payment rests on certain special features which are claimed to be peculiar to the time system.

When payment of wages is made without reference to output there would be no objection raised, perhaps, if the statement be made that the time system, as such, offers no inducement towards the obtainment of efficient output. A negative statement, however, is not strong enough, and the suggestion is made, therefore, that the influence of the time system tends definitely towards the restriction of output even if from a psychological standpoint only.

In stating that, under the time system, wages are paid without reference to output, it must not be overlooked that only a part of the truth has been expressed. The power of the employer to dispense with the services of any worker who may not be giving satisfaction can at once link up output and quality of workmanship with continuity of employment, and this in effect, to a certain degree, may be said to be the equivalent in its influence of payment by results. There is a measure of truth in this, but the whole ground is by no means covered.

The fundamental weakness of the time system is that, under it, no inducement is offered to any man to produce at his best. The operation of agreed hourly rates for the different trades has served to level the output per man down rather than up, and, in practice, it is found that the output of quick men shews a tendency to approximate to that of the man of average ability, and this in turn will usually be found to be less than what is reasonably possible. Quick workers are likely to keep their output on a slightly higher level than that of the average man so that, when trade is bad and work is short, their demonstrated superior skill will be likely to receive favourable consideration when discharges are being made.

In cases where such workers have been unwilling to reduce their output to an acceptable level, other influences have been brought to bear both by other workers and sometimes by foremen. Many instances have been known where the "next" job was not ready until sufficient time had been lost to ensure that the time which would have to be booked would line up with that usually taken.

Really, such a result is difficult to avoid. Assuming the supervision is all that could be desired, and the reference just made is certainly exceptional and not the rule, then unless it be aided by production statistics the supervision staff is in a difficult position, so far as insistence on a satisfactory measure of output is concerned, as without these statistics the time available for such investigations as are required is not sufficient.

Unfortunately, the operation of the time system is too often accompanied by a disregard of the value of production statistics; rate of output is treated as being of so nebulous a character that control or even, sometimes, intelligent comparison is of no avail. It is true that rate of output can be affected by many factors; that ability to produce as well as willingness to produce is necessary, and, what is not always sufficiently appreciated, ability is likely to be a much larger factor than willingness—a fact which has a much larger place in the worker's mind than is allowed for; but to treat rate of output as being impossible, not only of control but even of effective supervision, is deliberately to invite and encourage its vitiation, and to facilitate the fall, not only of the quick worker's output to the average, but of that average itself.

Remembering that man does not work for work's sake, but only that he may live, and, further, that his rate of remuneration is rarely all he thinks it should be, is it likely that the maximum efforts will always be voluntarily put forth, if at all. There can be little doubt that under the time system the rate of production voluntarily given is less than is normally possible, excluding the influence of skill and ability, and accordingly, as attention to the same is not in evidence, such rate of output that is obtained is likely to be less—but how much less nobody knows.

Seeing the effect of the operation of the flat or district rate in remunerating all men of a given trade on an equal basis, independently of their ability or will to produce, is to level the output down, it may be thought that if the quicker workers were paid a time rate in excess of the district rate, because of that skill, this would not only be equitable to the individual workers, but would also be acceptable to the trade societies, and would justify the men in giving of their best work, in output as well as in skill. Logically this would appear to be true, but in many cases this view is not acceptable to the trade societies, being, after all, in the nature of payment by results, and this would be more so as continuation of the increased rate of output, for which the higher time rate was paid, was insisted upon. The trade societies, while pleased to see time rates paid which are in excess of the district rate, are not keen

on seeing them given as a recognition of large output. Apart, however, from this, the practice of allowing time rates to reflect ability to give output, excepting the rate of output on which the increase is given be definitely maintained, is open to question, more particularly if the time rates of a large number of workmen be increased. In many instances where time rates have been so increased it has been found, after a short period, that the output tends to fall back to its old level. Should this not be the case, trouble of another character is likely to be experienced in the shape of other workmen seeking the payment of similar rates independently of their ability to produce. If a general increase of time rate be granted on this score there is no guarantee that a satisfactory rate of output will be maintained.

The author has in mind a works where what was equal to an increase of time rate of 25 per cent. was given in return for a promise "to work at piece-work speed." The output was increased for a few weeks, but was never more than 50 per cent. of that which was easily possible, and the novelty wearing off, output receded to its old level, but the increased wages remained, not being removable with the ease with which they were granted or at the rate with which output declined. In such cases it is not a question of reverting to the *status quo*; the old rate of output is gone back to, but at an enhanced labour cost in accordance with the increase of wages given.

It may be that in the bygone days, when the relationships of employer and employed were more familiar than those of to-day, together with the widely different commercial conditions then existing, the results obtained under the time system were quite acceptable, but even as these conditions—industrial and commercial—have changed so must the correlated conditions be changed or reviewed.

There is almost a parallel in the commercial world to the industrial "time" system, and the experience as shewn by the present-day tendencies is worthy of note.

At one time a large proportion of contracts was carried out on what is known as a "time and lime" basis with a fixed rate of profit, but with the altered conditions of to-day, due largely to the influence of competition, contracts of this kind are becoming very much the exception, although war conditions saw the resuscitation of the practice to some extent. Under this system no risks are taken as regards cost, and no inducement is offered to the manufacturer to concern himself about efficiency of output. It really is his "time" system, and his only definite obligation lies in delivering an article which will satisfactorily perform its required function. Cost at times has become a minor, and in many respects a neglected consideration, and during the war period this method of placing contracts was so much abused, as shewn by costs of production, that special steps had to be taken by the Admiralty authorities to reduce the number of contracts, so placed, to a minimum.

It is not suggested that manufacturers laid themselves out to take advantage of the terms, it is rather the psychological effect of everybody knowing them ; of their being aware that no loss was possible, and even when the manufacturers sought to carry out such contracts in an efficient manner they were foiled by the indifference shewn by their staff because of that knowledge. Thus the manufacturers' " time " system—the time system in commerce—has been tried and condemned, and for similar reasons to those which have been experienced in the industrial world.

There is another aspect of the question for which definite claims are made for the time system—in so far that under this system has been built up the world-wide reputation for excellence of British workmanship, which has made our productions so universally sought after ; that under this system craftsmanship has had the fullest opportunities for expressing itself, untrammelled by any considerations as regards time, the aim being first-class workmanship, and that under any other method of remuneration that reputation would be prejudiced.

That there is truth in these claims it would be folly to deny, and to maintain the reputation made must certainly be a chief aim just as much to-day as in the days gone by, but in pursuing this aim care must be taken that other equally important factors are not lost sight of or even underestimated. Not only have manufacturing and commercial conditions been affected by the tendency to eliminate contracts of the " time and lime " type, but the very existence of competition signifies a broadening of the sources of supply. Competition as known to-day was then practically non-existent. Lack of competition implies conditions akin to monopoly and this again gives a parallel to the time system. Monopoly conditions call for efficiency of product rather than efficiency of manufacture, and the time system calls for ability in craftsmanship rather than ability to produce quickly, which requires energy as well as ability.

It would thus appear that, to a considerable degree, our reputation for excellence of product was built up, in the first place, under non-competitive, if not largely monopolistic lines. The commercial conditions having been very considerably changed, however, it is necessary to review the industrial conditions to see to what extent they are capable of modification to meet present-day needs without impairing the quality of the product.

For the manufacturer, the acceptance of a contract at a fixed price implies that the cost of carrying out such contract, if less than the contract price, means profit, and if more, that loss will be involved. This necessitates putting on when tendering a sufficient cover for contingencies. If there be no competition such cover can be sufficient to meet the most remote possibilities, but if the reverse be the case, if the business be put out to competitive tender, then the probable cost of the work requires to be known within somewhat close limits.

Where material is concerned, particularly when markets are normal, estimating can be done with comparative certainty, but the cost of labour as reflected in output with its incidence on oncosts, is less easily dealt with, and, where it is thought the work is such that none but the time system can be effective, presents a problem of the first magnitude—the maintenance of excellence of product and the ensurance of cost being kept within estimate.

The question then naturally arises as to what extent the standard of excellence of product, as represented by workmanship, depends upon the use of the time system, and this resolves itself into the enquiry, as to whether excellence of workmanship is purely a matter of time taken. The evidence obtained in dealing with a large number of different works and industries gives a direct and very definite answer in the negative, and there are numerous instances which can be adduced in support.

In the first place, it is necessary to ascertain whether or not the ability or skill to produce work to a given standard is in evidence at all. There are " artists " who, in spite of all the teaching and practice possible, would not be able to produce one work of real art if a whole lifetime were spent upon its execution, although it might be noted in passing that artists are paid by results. In the same way there are workers who lack the innate skill necessary for the production of good work, and, while the expenditure of much time on a piece of work will afford the best opportunities to such a worker to produce good work, good workmanship is not assured thereby, while it will be obvious the costs must be high.

Further, the experience in many time-working shops is that, while the efficiency of the finished product may be all that could be desired, the obtainment of that standard is not necessarily the result of a high standard of workmanship all the way through manufacture, so much as a continual correction of faulty work, particularly at the final stages where the best skill is usually concentrated.

The suggestion is not that this is entirely or even in a large measure due to lack of skill ; in many instances it may be a lack of knowledge or instruction, although a contributory factor is the lack of direct interest in the need for efficient workmanship which is such a feature of time-working shops, due largely to the attitude adopted that the time system and efficiency of workmanship are inseparable.

A few typical examples may be given which are indicative of this, the firm concerned being one with a well-tried reputation for good and reliable work. The jobs referred to were in connection with the fitting and erection of a set of engines, and were amongst others brought to light in one week by men being paid by results, the machining, wherein the faults lay, having been done under the time system.

A. A liner was bored .005″ small so that undue scraping was necessary.

B. Two blocks were passed to the fitter bored .017″ and .03″ too small. In the ordinary way would have been filed and scraped; were returned to the machine for reboring.

C. A half bush was bored .008″ out of centre.

D. Holes drilled out of centre; would not assemble; had to be reamed out on one side.

E. The radius of a spherical block was turned .038″ out of truth and had to be corrected by hand.

These various faults were due as much to faulty organization and to a lack of standard of workmanship or specification of requirements as they were to indifferent workmanship, but their existence represented normal working under the time system, and until the fitters had started working under payment by results, were not known to the management, and even when voiced were doubted. After all, there is nothing illogical in this. The fitters who had been doing this work, making corrections as they were found to be necessary, did not feel called upon to complain. The work had been passed to them after having undergone what might be termed negative inspection—inspection which makes sure that parts are not spoilt, not that parts are in a fit condition for the next operation—and therefore might be taken as representing work accepted as correct. In any case, men say if "they were not doing one thing they would be doing another, and it didn't much matter whether they were chipping, filing, or scraping."

The experience in the one shop referred to is by no means exceptional, although different classes of product would have their own individual weaknesses; but the point to be made clear is this, that the time system itself offers no inducement to excellence of product, and the workmanship at intermediate stages can be faulty without attention being drawn to the faults.

The position, however, under a system of payment by results would take on an entirely different aspect. The receipt, by a worker, of material in such a state that more than a normal amount of labour would have to be expended to carry out the operation to be done, would be objected to on the score that no allowance for this had been made in the job rate and that to do it without receiving an adequate additional allowance to that job rate would be equivalent to paying for the correction of the bad work himself. He therefore calls attention to the faults disclosed, and as all other workmen, similarly affected, would do the same, a big outcry is raised and the opinion is formed at once, that the existence of bad work is of recent development and is due to the "scamping" caused by payment being made in accordance with results.

As has been argued, the trouble is one of old standing—it is the knowledge of its existence only that is new, and this, it must be admitted, has been disclosed by the influence of payment by results.

In order to provide against any kind of misunderstanding it can be stated that the argument is not that payment by results does not encourage bad work but rather that there is no real evidence,

in a general way, that excellence of workmanship can be obtained by the use of the time system only, or can be obtained with any greater certainty thereby, and the fear that to link up the amount of remuneration with output will be to risk the maintenance of existing standards of workmanship is a fear based on incomplete premises.

The deductions which appear to be most logical after consideration of the whole subject are as follows :

1. The time system by not linking up output with time taken offers no inducement toward efficient output, and when attention is not directed to differences of time taken which may exist, the slow worker may be eased of anxiety on that score, and indolence encouraged.

2. Excellence of workmanship is not assured under the time system, the chief factor being the skill of the worker and not the amount of time taken.

3. Under the time system no encouragement is offered to workers to improve methods of manufacture or to complain of faulty work, and the workers quite often allow faulty work to be sent to them without protest.

4. Under a system of payment by results there is a definite encouragement to all workers to increase output, and in so far that the methods used, the tools provided, and the condition of the material for working upon, either in the rough state or from the previous operation, are real factors in this connection, the interest of each worker is stimulated, all the time, towards the better use of plant, and the elimination of unnecessary work.

5. The standard of workmanship accepted is in accordance with the requirements of the management as interpreted by the workshop staff and does not necessarily reflect either the time taken or the system of remuneration in use.

True the factors referred to reflect in some degree the nature and the efficiency of the organization, but once the standards of workmanship are laid down and provided for, that system of remuneration is most to be commended which directs each worker's attention towards obtaining the biggest volume of output.

CHAPTER IV

THE APPLICABILITY OF PAYMENT BY RESULTS

It is a wise precaution, before any active steps are taken towards the introduction of a system of payment by results, to consider to what extent such a method of payment can be generally applied. Manufacture is such a composite business, requiring so many classes and grades of labour, mental, manual, skilled, unskilled, and clerical, and the operations to be performed can be so different in their character that a policy which may appear to be quite sound from the standpoint of accepted theory can prove to be most unsatisfactory in practice.

The policy of making payment in accordance with results is sound, provided the results are measurable and the application of the system can be made sufficiently general. If the system cannot be generally applied, however, the effect on those people who must be left outside its operation must be considered and appraised and the policy to be followed must be decided accordingly.

It is not always possible to-day for one works to be controlled entirely independently of other adjacent works, engaged in a similar class of work or using a similar class of labour ; the practice of each works has an influence on the others ; it may be in wage rates generally or with certain classes of work ; it may be with some concession made, or in the hours of labour worked, but any material difference, excepting there be some counterbalancing tendency of another character carries with it a corresponding advantage, or otherwise, which affects in some measure the practices of all adjacent works.

The position as between different shops or different classes of labour in the same works is of a similar nature, and any changes made in connection with the conditions governing the workmen in one section or trade are likely to have an influence on the remainder of the workmen who are not so affected.

The numerous operations to be done and the various duties to be performed in any works can be so widely different that it would be obviously impossible for them all to be subject to the same measure or treatment, and it is not uncommon to find that payment by results is applied to such operations in connection with the

direct work of production as are easily measurable leaving all others to be dealt with under the medium of time rates, standard or enhanced. Sufficient attention has not always been given to this matter, and many unwise practices have been started up with the object of overcoming the consequences of some decision which has been made without due consideration of all the facts.

Where the time system has been in operation for an appreciable length of time, the standard of wages of all employees will have been arrived at as a result of experience, and may be expected to reflect the relative value of the duties performed in the manufacture of the product. Under that system the wage rates at that level may be said to be balanced, but any change made in that scale in one direction will tend to upset that balance and necessitate its re-adjustment. This is precisely what can and does happen under payment by results, and it is desirable that the possibilities in this connection shall be appreciated before any changes are made. The steps once taken cannot always be retraced, but the wage balance if upset must inevitably be restored.

One of the simplest examples, perhaps, is that of supervision. Foremen and charge-hands are chosen from the ranks of workmen and, in a time-working shop for carrying out these onerous duties, are paid sums varying from 1 penny per hour or 5 shillings per week upwards above the time rates paid to workmen, and are, in many cases, satisfied with the remuneration paid. But so soon as payment by results is introduced the relation existing between the remuneration of workmen and foremen is upset, and excepting a new balance be struck, discontented supervision is likely to follow.

Similarly with inspectors and machine-setters, millwrights, toolmakers, "experimental" workmen, and out-workers who are generally recruited from the ranks of the ordinary workmen, the slight differences in pay which are made because of the more important nature of the work done are rapidly overtaken and the result is that these workmen who have been singled out for promotion because of their skill, ability and integrity find themselves in a worse position, relatively, than those whom they had left behind. It was by no means uncommon, not only during but before the War, to find workmen earning higher wages than their foremen, and this has been the cause of serious discontent, the fortunate workman being sometimes made to suffer by his less fortunate foreman who was the victim of such obvious injustice.

It may appear possible to refuse redress, but to think so is a fallacy as is speedily shewn when promotion of this kind is offered and refused because the man "cannot afford to accept." True, in such cases, it may not be impossible to get some men to accept the terms offered, but if these appeal to the third-rate workman only who, because he is third-rate, can afford to accept a wage which is actually less than that earned by a man of average ability, then the policy is a wrong one.

It will be found that the introduction of payment by results will have the tendency to increase the standard of wages of all the skilled men whether they are directly affected or not, and it is necessary to bear this in mind when considering changes of this nature.

The disturbing effect is not confined to the skilled and higher ranks but affects others, right down to the labourers. Because of the introduction of payment by results in different departments of engineering works, requests have been put forward on behalf of Trade Unions representing labourers, crane drivers and slingers etc., for increases of wages to their members or for the opportunity to earn additional wages on the grounds that as a consequence of the introduction of payment by results, their members were being called upon to work at a faster rate and that they were entitled to receive some benefit accordingly.

The argument is not illogical, but the question is not quite so simple as it would appear. The economic aspect must not be lost sight of. If the policy suggested were to be followed literally it would be possible to obtain an increased output at a reduced labour cost, so far as the operations were concerned, but by paying various people similar additions to wages, the economy secured could be frittered away leaving the position worse than before if only because the opportunities for further economy would be restricted.

An example of this kind is to be seen in the somewhat common practice of paying certain specified workers, who are working under the time system, an addition to their time wages, equal in amount to the average percentage of extra pay earned by those workmen who are paid by results. In the following illustration extreme conditions are assumed for the purpose of emphasizing the point.

Let it be presumed that in a given works 100 men are employed, 25 of whom are occupied on operations for which payment can suitably be made by results; further, that as a consequence of the operation of the system in use, the earnings of the 25 men have been increased by $33\frac{1}{3}$ per cent. and that, as a result of the discontent which has followed this change in the opportunities for earning, the remaining 75 men have been promised extra wages based on the average earnings of the 25. The situation would then be that because 25 men were known to have done $33\frac{1}{3}$ per cent. more work, being paid say £1 each per week for so doing, 75 other men, of whose efforts no real knowledge existed, would also be paid £1 each extra. Thus £25 would be paid in additional wages in return for extra work known to have been done and a further £75 would be paid for no better reason than to keep the other men quiet.

It should be a first principle that extra wages should be paid only when some adequate additional output was given or ensured. To say that the increased output obtained from the men employed directly on payment by results makes it possible for the whole of the men to benefit is a most superficial and elementary argument.

Temporarily that may be so, but in business long views are necessary; the conditions of to-day may be vastly different from those which will obtain to-morrow, and it is most desirable that to-morrow's actions and policy shall be untrammelled as far as is possible.

The fundamental objection to making payments to one class of workers on the basis of the efforts of others is that there is no link between payment and output. Superficially it is not illogical to suggest that where the output of the workers engaged directly on production had been increased by, say, 50 per cent. as a result of the operation of a system of payment by results, that a similar increase of output should be looked for from these workers who are engaged on those operations for which payment is not made by results. If, however, the increased output given under payment by results does not call for a similar increase of effort from these "indirect" men, and it rarely does, then it is not logical for their wages to be increased in that proportion.

Payment by results has been introduced into works and has been instrumental in increasing output by at least 100 per cent. Although wages have not been increased in like proportion, the increase secured has been sufficient to upset the balance of wages. Applications for increased wages have been received on the grounds that the men concerned were called upon to work proportionately harder. In some instances, instead of granting either increased wage rates or a bonus based on the earnings of others, a direct system of payment by results has been applied, with the result that even with the increased work called for, the number of workers required has been found to be much greater than necessary and has been reduced. Had the payment of a bonus based on the earnings of those paid by results been adopted, these excesses in the number of workers employed quite likely would not have been disclosed.

This has been found to be a general experience, and in practice, as well as in theory, has proved to be an unwise and inefficient arrangement. Reference can be made to a collective system of payment by results, for which it is claimed, and rightly so, that the balance of wages is not upset by its use.

Under this system, known as the "Priestman" collective system, every employee from the office boy and the lavatory attendant to the highest officials, is paid an addition to wages equal to that by which output has been increased; that is to say, that in direct proportion to that by which those engaged in production have been able to increase same, the fitter at his vice, the foreman in his shop, and so on, the office boy, whose influence on output is nil, will be remunerated with an addition to his wages equally with the fitter and foreman who gave the increase. Thus a lavatory attendant may receive an addition to his wages of 50 per cent. and a stoker, likewise, when neither of them, in the slightest degree, may be efficient, and the latter, in fact, might be most wasteful.

It is possible, of course, in a well-managed works for a method to be applied which, although not sound in principle, may give results which are not entirely unsatisfactory. Where close attention had been given to all grades of labour, prior to the introduction of a system of payment by results and the numbers employed reflected reasonable requirements, little harm may be done by following either of the methods discussed, but such a policy should not be embarked upon until after the facts have been ascertained. Grave risks can be taken in this manner without a commensurate return being either secured or made possible, and, perhaps, the most likely result, where this policy is followed, is that workmen will be attracted from adjacent works because of the high wages paid without relation to output. This was particularly noticeable during the period of the Great War when the most inefficiently run works, because of the wasteful wages paid, attracted the workmen from other works which were better controlled, encouraging, thereby, if not justifying, the abnormal demands which were such features of those times.

With the desire to restore the balance which the application of payment by results to sections, only, had upset, the notable 12½ per cent. bonus to time-workers was introduced. There is no doubt this was a most ill-thought-out scheme, but, after all, some steps were necessary in the circumstances, and the misguided politician stepped in, while the engineer, with whom the responsibility lay and who had allowed the unsatisfactory situation to grow up, did nothing. The object of the 12½ per cent. bonus was right, the basis upon which it was paid was wrong, but not more wrong, either in principle or in practice, than as though the payments were made to one class of worker on the basis of the amount of work done by another and independent class.

In both cases something was done to restore the lost balance of wages. With the 12½ per cent. bonus, this was the sole object ; when payment of a bonus is based on the earnings of others, the regaining of the lost balance is the ultimate object, but the influence on the immediate object—increase of output—is so remote or insignificant as to be negligible and is little better in principle than that much condemned "12½ per cent." The first aim should be to apply a genuine direct system of payment by results to as many classes as possible. This can be done wherever the operations to be carried out can be defined and are measurable and these are more common than is sometimes thought to be the case. Amongst them are to be found two of the most important, tool-making and millwrighting. There are other classes, however, which cannot conveniently be brought within the operation of a direct system of payment by results, such as foremen, charge hands, ratefixers, machine-setters, and inspectors, although, in certain conditions, the latter is subject to question. To arrive at an informed opinion as to the best method to use it is necessary to examine the influence of the various grades of workers on the success and the output of a works.

Starting with the managing director, his influence would be reflected in the general trading results rather than in the fact that men worked hard or idled, or that the works organization was efficient or otherwise, and his success would be measured in accordance with his responsibilities and the factors operating. A works manager's efficiency would be judged, primarily, by the manner in which delivery dates were kept, by the efficiency of the product made under his control and the consequent cost. Into this would enter the cost of materials, of labour and oncosts, and these would reflect choice of staff, wisdom of policy and ability to control. The amount of output alone would not be the true criterion of a works manager's success, nor should it be made the basis of any extra salary paid ; cost is a crucial point.

The influence of a head foreman, on output and cost of production, would be shewn by the way his departmental delivery dates were kept, by the economy of his production and the efficiency of the individual unit. These reflect organizing ability, choice of workers, practical knowledge of the function of the product and of manufacture and his control of both workers and staff. The assistant foreman has similar duties and responsibilities, but these are sectional rather than departmental and are narrowed accordingly.

The whole of the officials in these classes receive and give orders, arrange and organize, they do not engage in manual labour, and their duties being administrative their success in the carrying out of those duties will be reflected in the amount of efficient product turned out rather than in the amount of money earned by the men working under their control.

Into a slightly different category falls the machine-setter, who prepares machines for carrying out operations, the machines to be attended by unskilled operators afterwards. In this case the machine-setter, by virtue of his knowledge and skill, becomes the senior workman and uses a certain amount of authority of a supervisionary kind but has no responsibility as regards organization. Accordingly as he is efficient as a workman, attends to his duties, and sees that the machines in his charge are kept running, so should the output be satisfactory in quality and volume, and his efforts would be accurately measured by the output obtained from the machines set by him.

It has been the practice to look upon tool-making and millwrighting as being work of that character which cannot be dealt with by a direct system of payment by results, and it was owing to this, to a considerable degree, that the 12½ per cent. bonus was instituted. While this has long been disproved in works progressively managed, it is still held in others to be so difficult as not to be worth the trying. It is not possible to say more, effectively, than that it has been tried with most satisfactory results in a number of works and that there is no undue difficulty.

The exceptions would be where, as in the case of the tool-maker or millwright, a man may be told off to attend to minor faults or

adjustments as they arise, for which records would not be worth while, either of their happening or their individual cost, and the making of job rates, if the jobs were always verified, would be too costly. In such cases, the arrangements for which should always have the works manager's sanction, the appropriate method of ensuring the obtainment of that man's best efforts would be to link up his wages with the output obtained from the machines attended to by him.

Inspection is a difficult subject. Theoretically speaking, inspection can be carried out advantageously under a system of payment by results, and in some works this has been done for many years. At the same time there is a grave danger, inasmuch as the inspected article bears no sign of its having been inspected, and in many instances where the workman who has performed an operation is known and can be relied upon, his word is taken that jobs are right, and pieces are passed by the inspector without any attempt being made to try on the gauges. In other instances a percentage only is inspected, but the full number being allowed for as necessary, and all being booked in as inspected, very large earnings are made because the work has not been attempted.

It may be said, why not allow for a percentage only to be inspected? Such an arrangement is worse. In the former case the responsibility for faulty parts being passed is that of the inspector; in the latter there would be practically no responsibility excepting in those cases where nearly all the parts were wrong. Where the customer has an inspector who makes a detailed examination himself, or where the test is of such a nature that faults would be disclosed, inspection under payment by results will have less risk; but their reputation is always the stake a firm must be prepared to risk in order to have their work inspected under payment by results.

Of course, it is possible to have a super-inspection which will deal with certain batches of work chosen and examined by the chief inspector or a senior assistant, and, if the results are not satisfactory, to discharge the man concerned. This latter policy is necessary in some instances where inspection is carried out under the time system. There is no guarantee under any method of payment that all inspection will be efficiently or carefully done, and the desire for big earnings under payment by results, in some instances, has no worse effects than has indolence under the time system.

This, however, does not help to restore the lost balance of wages, and it will depend upon the nature of the work whether it will be wise to link up payment with output. The method which would carry the least direct appeal, and therefore would offer the least inducement to pass faulty work, would be to base the payments to be made on one or other of the following: on the average earnings of the total number of workers employed directly under payment by results or of those who are employed in the fitting or

assembly shops, or on the total output for given periods, when sufficiently short periods could be arranged. The latter method is preferable, inasmuch as the interests of the inspectors would be directed towards passing good work, rather than to a desire to see the operators earn big wages which would react on their own, and to finished output, the volume of which would be decreased if faulty work were passed along. Failing the arrival at some scheme which gives promise of satisfactory correlated results the only alternative would be to give an increase in time rates to approved inspectors. This need not, necessarily, be equivalent in amount to the earnings of those workers who are paid by results, an increase in time rate being looked upon, generally, as having more real value than a possible addition based on job rates and effort. As with other classes of labour, some review as to the numbers employed is necessary to guard against the employment of too large a staff.

The remaining grades are to some extent unskilled workers to whom the balance of wages is a less direct question. Not only so, but the duties carried out, as of store-keeper and of general labouring, are so often of such an intermittent character that full employment of the time for which payment is made is rarely called for. In such cases, ease of job, in fairness to others who are continually employed, should be considered, and where full occupation cannot be offered, such jobs should be treated as stepping-stones to others where better opportunities exist, rather than as justifying the payment of a sympathetic increase of wages as a matter of course. While the aim should be to be fair, always, to all grades of labour, it cannot be forgotten that the proposition is one of business, not of philanthropy, and that, excepting there is a definite and adequate return for the additional wages paid, the making of such payments will be fundamentally wrong and a source of weakness.

In some instances it is possible to provide labourers with definite tasks for which job rates can be given, although if these are not of sufficient magnitude to provide employment for periods of not less than one day, then opportunities are offered to "wangle" the time by booking less time to the payment by results job than actually spent, obtaining thereby extra pay, part only or none of which has been earned.

Of a slightly different character is the practice of paying labourers a small sum per pound of non-ferrous metal swarf and short ends collected and taken to the stores. The object is to encourage an interest in the avoidance of waste which is so common in this connection, and usually an increase in the returns to store follow. Some care is required, however, to make sure that, in the desire to obtain large bonuses, good metal is not included, and that no tricks are played, such as the use of oil or water to make the swarf weigh heavier. At the same time, this has no connection with output, and in directing attention to swarf, neglect of other duties more closely connected with output may be induced.

The question is one which can be discussed in broad principle only. The conditions existing in different works vary so widely, both as to organization and class of product, that the policy to be followed must be decided individually for each works. In Chapter XIII. a number of methods are discussed which may be helpful guides when decisions are being made, but the important point is that the facts shall be considered before rather than after the event.

CHAPTER V

THE RESULTS FOR WHICH PAYMENT IS TO BE MADE

If the inward reasons for the trouble experienced with the operation of systems of payment by results be ascertained, it will be found, probably, that much of this has been centred around the results paid for, rather than the method used or the amount of payment made. It would be shewn, probably, that some of the results paid for were not those for which payment should have been made, nor really for which it had been desired or intended to pay; in other cases, results which justified payment in some form would be found to have been paid for under the wrong method, from the wrong account, as it were, and that the troubles experienced, while associated with the principle of making payment in accordance with the results, were really due to the policy followed and did not necessarily affect the principle at all.

Nominally, by the term payment by results it is understood that the amount of wages paid will be in accordance with the quantity of work done either in an equal or some definitely stated proportion. So far this is a plain straightforward proposition, and the method of payment decided upon, together with the relation of output to earnings, might be thought to comprise the greater part of the problem. This would be the case if the results for which payment was to be made could be so simply treated.

An examination of the various steps taken in connection with the remuneration of labour, more particularly where earnings have been linked up with output, will indicate that, generally speaking, more attention has been given to the question of payment than to that of results; and further, that the results desired have usually been assumed to be a matter of workers putting forth additional energies. If this assumption had been correct, the methods devised for remedying the position would have proved reasonably successful, but, as is being recognized more fully to-day, output can be influenced by many factors, of which workers' efforts form but one, and that one, possibly, not always the most important.

It appears desirable to define the scope of payment by results from the standpoint of its logical application and possibilities. In

the first place, the existence of payment by results at all is an acknowledgment that under the time system rate of output is less than that which is considered reasonably possible, and that to link up volume of output with amount of remuneration will tend to overcome this deficiency. This is a reasonable assumption and is quite in keeping with the facts and the opportunities, and there is no doubt that, from a constitutional standpoint, the appeal of payment by results to workers to put forth greater efforts is a correct one, and one to which a good response has been made ; the range of the appeal, however, in its legitimate sphere, can be extended no farther than to ability and energy, as applied to the practical work of production, and payment by results has no appropriate application in any other direction. This must be so, otherwise payment by results would strike at the very foundations of law, order and control.

In just the same manner in which a seaman needs to carry out the orders of his captain when sails have to be set or furled, carrying out such orders in as quick, efficient and workmanlike manner as possible, so is it necessary for the worker in the workshop to carry out the instructions given him. Like the seaman, he has no responsibility for the correctness of the order but only for the efficiency of his own work, and, therefore, is given no authority for independent action, and without authority a man can do nothing further, constitutionally, than obey orders. Then so far as the worker's constitutional opportunities are concerned his influence on rate of output is confined entirely to the efficiency of his own efforts when carrying out the orders given him.

This is not to say that workers cannot be of use in other directions ; they have been, can continue to be, and it is desirable they should so continue ; but such assistance as can be rendered which is independent of the efficient carrying out of instructions is not of that nature payment by results is intended to cover, and is not fitly remunerated thereby. If the assistance of workers be required in other directions, then the nature of such assistance should be capable of a definite specification, in which case direct arrangements ought to be made for securing the results known to be possible, and whether the person used be a worker or not, his remuneration should be arranged on some definite basis so that its amount and duration could be known, but, while it may be desired to make such remuneration in accordance with the results achieved, the basis adopted should be an appropriate one.

If, however, the assistance of workers be sought to remedy a state of things which is thought rather than known to be bad, and there is no definite knowledge as to possibilities, then the policy is really a blind one, and is not unlike that of a man who has a pain ; there is no doubt about the existence of the pain, although nothing is known of its cause, but instead of trying to find the reason for its existence so as to apply a suitable remedy, a patent medicine is resorted to in the hope that some relief will follow. There is a

chance that a cure may be effected, but it is most uncertain, and, in any case, will depend upon the patient's physical condition. Accurate diagnosis is essential if a state of health is to follow with any certainty. What can be the consequences of the use of the wrong methods in this connection?

In the main, the weakness of applying the wrong policy is felt in two directions. In the first place, there is no certainty as to the equity of the reward either to worker or employer, while in the second, output is stabilized on too low, and cost on too high a basis.

Where the increased output obtained is the direct result of the workers' ability and effort it is fitting that, so long as an operation is continued, using the same method, class of machine and tools for which the job rate may have been fixed, the same job rate should apply; in fact, no other practice would be fair, and so far as these are the results paid for, the use of payment by results is correctly applied. So soon, however, as output is increased by workers' aid by means other than the expenditure of effort, then the application of payment by results ceases to be appropriate, as a little examination will shew.

Suppose the cases of two workers be taken who, on their own initiative in the desire to make larger earnings, improve on the methods in use so that the output can be increased by 50 per cent., and consequently, where the piece-work system is in use, increase their earnings as well. Of one part there are but a few pieces to make and the opportunities for increasing earnings cease after, perhaps, a few hours' work. For the other part the quantities to be handled are large and continuous manufacture is possible. The reward to the respective workers for ideas of possibly the same relative merit, summed up in money, would be vastly different. If under the job rates given the estimated weekly earnings had been 60/- and the output had been increased by 50 per cent., then under the piece-work system the weekly earnings would have been increased to 90/- per week and the return to the worker in each case as a result of the enterprise shewn would be at the rate of 30/- per week. In the one case, however, this would mean say for two days' work, not more than 10/-, while in the other it would mean £75 per annum. The question which arises is this: what was the intrinsic value of the suggestion? Was 10/- a sufficient reward in the one case and is £75 per annum too much in the other? Is the latter an economic price to pay for the improvement made? As a matter of equity the workers concerned should have been rewarded, but by other means.

There are instances where output has been increased, not by improved methods on the operation directly concerned nor by the expenditure of a single extra effort, but solely by the elimination of idle time or of unnecessary work. It could be argued that if, as a consequence of the influence of payment by results, slack supervision or bad organization had been overcome and increased output obtained, there would be nothing illogical in paying for

same under the conditions of the system under which the increased output was secured. Superficially this is true, but as a business proposition it is not sound.

Let the example No. 25 given on page 33 be taken a stage further. Due to two men being used when one only could be profitably employed, the job rate was double what it should have been; 45 hours too much and this on the Halsey-Weir system at the rate of 1/- per hour means 22/6. "Mechan" doors will be used probably for the next 20 years, and so long as the same method of hanging is used it will be somewhat difficult to effect an alteration of job rate; 22/6 per door must continue to be paid because the supervision had once been so slack as to allow time to be idled in the manner indicated. In a large shipyard, doors of this kind are continually being hung, and if two doors per week per annum be considered for a period of 10 years—not a long period where history is concerned—1000 doors will have been hung at a cost of £1,125 greater than the actual value of the work—an amount nearly as much as the fitters' time wages for the same period. This was indisputably a case for supervisionary measures for which no additional effort was called, and no payment whatsoever was justified.

Similarly, if organization be faulty, if the tool service be bad, if there be an insufficient supply of work, these weaknesses ought to be remedied by means other than the use of payment by results. In a new department output was low, and payment by results was introduced as a corrective, the job rates being based on time taken. The output was improved but was still low and, on the matter being investigated it was found that all cutting tools had to be taken personally to the smithy, 300 yards away, to be dressed, waited for, ground afterwards in the shop, a second visit to the smithy being necessary to get the tools hardened. All the time so wasted went into the records as time taken, and later, when the conditions were improved—a gradual process—the job rates so fixed stood and reflected for all time the unsatisfactory conditions which existed when the department was inaugurated.

Again, a planing machine, but a few years old, had been used intermittently on one job ever since it had been installed, and the heaviest cut which could be taken was .5 of an inch deep at 16 feeds to the inch. The planer was known to stick to his work, and it was suggested that his records might safely be accepted as a basis for job rates. These, however, were so different to the rate of output which seemed possible that investigation was made. It was found the machine would not carry a heavier cut than that stated, but when the reason for this was investigated it was discovered the forward belt was saturated with oil and was running with only one half its width on the driving pulley. The source of the oil supply was eliminated by the provision of a suitable tray, the striking gear was adjusted and a cut of double the size was at once possible.

If, however, the time taken had been used as a basis for the job rates, the planer would have surmounted the oil and the striking gear troubles himself and the firm would have paid weekly for an indefinite period large sums, comparatively speaking, for the fitting of a much-needed oil-tray, while the increased output would have been held to be an example of the value of payment by results.

Evidence as well as logic go to emphasize the necessity of applying the right measures in the improvement of rate of output ; to pay for improvements in accordance with the manner in which they are made. In so far as workmen's abilities and energies are variable quantities and affect the results accordingly, then output is the right basis on which to pay. On the other hand, seeing the faults of organization and supervision are not corrected by the exercise of workmen's energies, then improvements obtained by the elimination of these faults, should be paid for by a lump sum, or by promotion, or by any means a firm may choose other than by the agency of payment by results.

The only basis which can stand the test of time is that of the value of the work to be done under the most efficient conditions the plant and works provide ; to be exclusive of all other influences, whether of supervision, organization, supply of work or the state of repair of the machines in use. The situation was once somewhat pitifully epitomized by an assistant manager, who, as soon as he knew that it had been decided that payment by results was to be introduced into one of his departments, said, "I suppose we shall have to put the shop and the machines in order now so that the men can make bonus."

It is this indifferent attitude to output, the frequent accompaniment of the time system, which tends so much to impair the possibilities and makes it such a matter of urgency to analyze the situation for the purpose of ascertaining what results are possible and why, and of deciding in what manner payment ought to be made.

Consideration of the subject makes it increasingly clear that the introduction of payment by results as a first step towards obtaining efficiency is a mistake, and that adequate knowledge of the whole position is necessary first so that the remedies applied shall be likely to achieve the desired results as economically as possible. In some of the examples cited in Chapter II. efficiency of output was shewn to have been obtained but not at economical cost, and there can be no doubt that the ultimate aim must be the obtainment of costs, in which efficient output is fully reflected.

There is another side to the question, which requires careful consideration, apart from the direct one of cost, if the right results, only, are to be paid for. It is necessary to define the relationship between output, effort, and cost. The idea of the man in the street, and sometimes of the man inside is, that an increase of output must be, of necessity, the result of harder work, more concentrated

effort on the part of the workers, and that, as a matter of justice, wages should be increased in the same proportion as that by which output has been increased.

Superficially the idea is not illogical, but it can be very far from the truth, and is the more likely to be so as knowledge as to what the position actually is, is deficient. Example, experience, and the existing situation as regards payment by results all go to emphasize the fact that the rate of output obtained under the time system does not reflect the result of continued normal effort. While these are sufficient to prove that increased output does not necessarily call for additional efforts in the same proportion, something further than proof has to be considered.

Where the rate of output obtained has been much less than that which was possible, the ideas of workers as to what should be the basis of payment are sometimes very definite. In a sheet-metal working shop a system of payment by results had been introduced. Organization might be said to have been represented more by its first letter than by any tangible evidence; the supervision, too, was weak, and the output obtained was not more than 40 per cent. of that reasonably possible. The men knew the time the various jobs had taken, and this time, in the absence of any complaint from the foreman, represented to them satisfactory performances, and they were looking forward to their job rates being based accordingly.

Obstacles to production, however, were removed, thereby converting what previously was unavoidably idle time into production time, and by so doing, made increased output possible without any additional exertion being required. This was not the view of the workers concerned. Their contention was that the firm had been willing to pay time rate when 100 hours had been taken for a given job, and if they as workers were to give increased output they must have increased wages accordingly. If the firm had been willing to pay them for taking a long time before, they would be better able to make similar payments when more work was being done in a given time.

Increased output was obtained, and at a reduced cost, but the job rates given were much higher than they should have been, for the reason given. Should that firm not be called upon to meet the competition of other firms whose future costs of production have not been mortgaged in this manner, no trouble may be experienced, but so soon as that does happen, either orders must be taken at a price which is too low or job rates or time rates will require attention; otherwise orders will be lost.

In the same manner by which, under the time system, workers can be prevented, by faulty organization and bad management, from giving that measure of output which is possible and which they may be prepared to give, so by the removal of those obstacles to production can the output be increased in volume without calling for any increased effort whatsoever on the part of the workers;

and even as it has been unfair to lay to the charge of workers the whole of the responsibility for low output, so is it wrong to make additional remuneration to workers simply because obstacles to production have been removed. Moreover, if efficiency of output and cost is to be the aim, the basis must be efficiency, and the only factor definitely known about output as it is normally obtained under the time system is that efficiency is not reflected therein, and efficiency cannot be obtained from a basis of inefficiency—ignorance of facts.

In using a remedy which is not the right one, the effect on the workers concerned should be considered. It would surprise a good many manufacturers perhaps if they knew just how shrewd an idea many of their workers have of the way in which their businesses are managed. True, workers have a very decided fear of "the office," but that attitude is capable of much misconstruction, and the movements made by management are quite frequently weighed up not only for what they are but for what they imply. For example, the workers often have a much truer knowledge of the foreman's capacity as a technician and as a supervisor than has the manager, and know which string to pull and how far to pull it, and when payment by results is introduced when other measures are called for, like a smart salesman the worker takes steps to make the best use of his employer's bad business deal. More money for more output gives him a claim to the whole field, independently of its state, and he seeks to consolidate his position and often succeeds in doing so.

The manufacturer can no longer afford to treat payment by results as his only means of achieving efficiency. In doing so, especially in works where output is unduly low, he is making a confession of inability either to control or to diagnose the real cause of his trouble. If low output be due to slack supervision the appeal is directed to the overcoming of that fault ; if organization be the cause of the deficiency, the appeal is for help to improve the organization. Official labour presses in some quarters for a share in the control of industry. Every time payment by results is introduced and output can be increased more by the improvement of supervision and organization so often is there an acknowledgement that, to some extent, the labour policy is justified and that the control of industry should be shared.

The only results for which payment ought to be made under this head are those which follow the use of the properly directed brains and energies of the workers in conjunction with the use of plant in a suitable state of repair ; a supply of tools satisfactory for the purpose and obtainable as required, without delay, and a sufficient amount of work to make continuity of effort possible. Given these conditions, the existing rate of output might be expected to be of an efficient character, but this cannot be assumed to be the case, and some investigation is necessary for the purpose of ascertaining what are the actual facts ; it is only when statistics

are compared or when the results are analyzed that an adequate idea of the true position can be obtained.

In this connection the ideas of management are no more reliable than are those of the workers. There is nothing more deceptive than one's own general ideas as to what are the possibilities of output in a works in which some years have been spent. Many managers speak quite positively as to the efficiency of their works, forgetting that efficiency is a comparative term, excepting some absolute standard is used wherewith comparison can be made.

This does not necessarily imply incompetence or negligence; in a number of cases it has been known that the arrangements made by management have been excellent, but either these have not been observed by the staff or obstacles have been encountered which prevented the desired results being obtained, and there being no production statistics or other link whereby the facts could be made known, unsatisfactory positions have not been disclosed. (See example No. 8 on page 19.)

Whatever method of remuneration may be in use, nothing can be taken for granted where efficiency is concerned. Statistics, cold facts, are of infinitely more value than opinions, and when these are obtained and compared it will be found possible oft-times to take a much stronger, and possibly a more generous line than would otherwise be the case. The weakness of production engineering has been the lack of detailed knowledge of possibilities, and this to a considerable degree has been the cause of many of the difficulties with payment by results; payment can only be made, safely, from the standpoint of economics and of industrial contentment, for results which are not only known, but known to be the right ones. The basis must be opportunity, value of work as indicated by proved data, not as coloured by the time taken by workmen whose abilities are not known, under a system whose influence is acknowledged by all parties to be at least negative and under conditions of which there is no record.

CHAPTER VI

INDIVIDUAL OR COLLECTIVE SYSTEMS

THE various systems of payment by results can be divided into two main types, the individual and the collective. In a general way, the terms themselves indicate the difference in principle between the two, but some definition is really necessary if the position is to be clearly understood. It is usually recognized that the term "individual" is applied to those systems which enable each worker's efforts, as reflected in accepted output, to stand alone for the purpose of computing any extra pay which may be earned, and that the term "collective" is applied to those systems where the efforts and output results of all the workers are pooled, the resultant extra earnings being shared either equally or proportionately.

The most cursory examination of the question, however, will indicate difficulties in deciding when a system is collective or individual. If it be contended that for a system to justify the use of the term individual, it must be possible, always, for the efforts of individual workers to be kept separate for the purpose of computing the extra pay earned, then the individual system, theoretically, does not exist. A system can be termed individual or collective accordingly as the reference is to worker's efforts or to jobs. Actually there are many instances where more than one worker is needed; for example, the smith and his striker; the plater and his helper; machine erection, which may require one, two or twenty men. Taking the case of the smith and his striker, it cannot be said, logically, that because they work together, and the object of their combined efforts is one and the same, that such constitutes the principle of the collective system; or if two fitters are working together on one piece of work that the individual system does not obtain, and what is true where two men work together must be true of twenty.

The true definition of the terms would appear to be found in the application to the job rather than to the worker, and this is reflected more or less in every-day practice. For purposes of the consideration of the two principles, the individual system will be considered to apply when a separate job rate is given for each completed and

measurable stage of manufacture, and the collective system will be taken as applying when the job rate links up, for purposes of extra pay, the results obtained from different operations which have no direct bearing on each other as regards output.

There is no doubt that proof can be advanced to shew that output can be improved by the use of both systems; at the same time mere improvement is not a sufficiently high aim, efficiency of output, as an essential condition of economical cost, must be the goal. Many conditions have to be met in connection with different classes of manufacture and, in fact, in different works where the product manufactured is similar, and these conditions ought to be taken into consideration in deciding whether the individual or the collective system shall be used. While the decision to treat the individual system as obtaining when a job rate is given for the work done during each completed stage of manufacture might appear to be a logical one, it will be of value to consider some of the conditions of manufacture obtaining, together with their influence on individual and collective output.

There are classes of manufacture where the efforts of a number of workers are required before anything of a measurable character is produced and where segregation of effort or results is either impossible or would serve no useful purpose. A useful illustration may be cited from the manufacture of paper.

The manufacture of paper may be described as a continuous process into which numerous operations enter, many men being employed. The material is continually and automatically being passed from one operation to another until it is turned out as finished paper on the reel at the end of the paper-making machine. Although some of the men concerned may not see the finished product at all, their entire efforts are directed toward the preparation of "stuff" which will give the required quality and tint of paper at the end of the machine. Thus the aim of each man in the gang is the same, and it is fitting, in fact no other method is logical, that, under any system of payment by results used, the extra pay earned should be decided by the amount of good paper made. In this case what would really be done would be to give a job rate for the process or operation of making paper and this conforms to the requirements of the individual system. This work may be said to be collective in character, and if, consequently, it should be desired to label the system used as a collective one, because of this, the question at issue would be one of name only.

In engineering, continuous processes are not common, but the manufacturing organization can be such as to present somewhat similar conditions. If, for example, a workshop be specially laid out and tooled up for the manufacture of a given piece, and the arrangements are such that the pieces are passed from one machine to another until all operations are completed, then although actually each operation could be complete in itself and be measurable accord-

ingly, the influence of the manufacturing arrangements would be such that, so far as output was concerned, the conditions would be equivalent to those of a continuous process without having a measurable intermediate stage. The organization of the work, in such a case, might be described as being collective in its character, and, as with the continuous process mentioned, the only method of measuring the output results would be to consider the number of articles completed. This again may be argued as involving the collective principle, but if the question be examined further it will become apparent that the conditions have special features which require to be made plain.

In both the illustrations given, either the process or the organization of the work is such that no one person could definitely increase output ; each worker would be expected to handle that material which came to him, and provided such handling were satisfactorily done, that would represent the sum total of that individual's influence on output. In both instances, the worker handling the first operation could hold up all the rest, while he who handled the last operation could hold up or retard the whole output. Thus, always assuming the arrangements for intermediate operations and the manning of same are satisfactory, the effective units so far as output is concerned would be the last in each case. The process or sequence once commenced, the economy of intermediate operations would be a question of the manning of same rather than of individual effort, because with the supply of material to be worked upon limited in amount by the requirements of the process or by that passed from previous operations, the task of each intermediate worker would be to handle that amount of material only which was passed to him, beyond which he could not go. Then if the work so involved could be done in one half the time in any one of the intermediate operations, no increase of output could follow ; the supply of material being limited the worker would be idle by arrangement. The correction of a weakness of this kind could not be overcome by any system of payment, and would be a matter for the shop foreman to rectify. It will be obvious that failure on the part of any one individual to perform his portion of the work would be reflected all along the line, and that the output finally obtained would reflect the degree of efficiency of the gang as a whole, or, in other words, of its slowest member or operation. It is in such instances as these that good results could be expected under the time system because of the ease with which the results obtained could be reviewed.

To summarize, where the process or the organization makes operations collective in character, the amount of output obtained can be readily compared with that possible ; the economy of production, so far as intermediate output per person is concerned, is as much a matter of organization as of effort, while the possibilities of the influence of payment by results are counterbalanced by the fact that good supervision can easily make itself effective.

A further illustration might be given in which the collective system is shewn as being applied to several machines each of which has four attendants.

Paper is made in the form of a wide web, in long lengths, wound on reels. To prepare the paper for the use of the consumer it must be cut into pieces of suitable size. This is done on a "cutting" machine, there being, where the pieces cut are laid by hand, sometimes as many as four people required per machine. To pay by results, on the individual system, for the paper cut would necessitate a job rate being given for the whole of the paper cut by one machine, and this would cover the efforts and results of all the people required to attend one machine and to deal with the paper cut by it.

If instead of there being but one cutting machine, there were, say, a dozen, and an overall rate were set for the whole of the machines, then, inasmuch as the workers on one machine could have no influence on the output of any other machine, the arrangement of one rate to cover all would be an application of the collective principle, although obviously it would be to the general advantage if, from each machine, the best possible output were obtained.

The application of a collective system, if the collective principle is to be given a real opportunity to shew its value, becomes restricted, almost, if not entirely, to work where the respective operations are not directly connected with each other so far as unbroken continuity of process is concerned, and where the results must be reviewed individually if real knowledge as to shop efficiency is desired.

The use of the collective principle as discussed here is of comparatively recent introduction, the most notable example being that introduced by Messrs. Priestman Bros. into their works at Hull in 1917. The output results obtained through its use have been undoubtedly good, but as introduced by them leaves their direct labour costs 10 per cent. higher than before, they having given an increase of wages of 10 per cent. when the system was introduced, making at the same time their existing output and labour costs plus this 10 per cent. the irreducible basis of payment. In spite of its comparative infancy, the system has been advocated widely, and somewhat extravagant claims have been made for it as a means of avoiding or reducing industrial discontent. It is claimed that its use obviates the need for cutting job rates, the great evil of the individual system, as well as the jealousy supposed to exist between worker and worker over the difference in their respective earnings which is possible under that system.

Any system through which increased output can be obtained and industrial discontent avoided is deserving of the most careful attention, but it is essential that the results obtained shall be such that the efficiency of output and cost combined are not prejudiced, because, after all, industrial contentment is not an end in itself.

What are really the advantages and disadvantages of the two types of payment? Taking individual systems first, as having been

in use for the longer period, it must be admitted that many complaints are made regarding them. Officially, in trade union circles, they are not favoured, but this by itself has little significance; officially, in trade union circles, there are few features of the present industrial system which are favoured, but that does not mean, necessarily, that immediate changes must, ought to or can be made. Actually, the three main objections the trade societies have to individual systems—collective systems have not yet had a sufficient tenure of life to have completed the circle—are:

1. The cutting of job rates.
2. The shortness of work supposed to follow the introduction of payment by results.
3. That the individual system in making earnings depend upon successful individual effort encourages competition and sets one worker against another, causing jealousies and bad feeling.

It is due to complaints of this character—although the second one would be common to all systems, and therefore need have no special reference here (see Chapter I.)—that attention has been given to alternative methods, which, while preserving the principle of payment by results—the aim being maximum output—would tend to avoid as far as possible the objections put forward.

In connection with the complaint that individual systems cause jealousy and bad feeling between worker and worker, it is of some interest to note that in their Report of March 21st, 1917, the Departmental Committee, appointed by the Board of Trade to consider the position of the Engineering Trades after the War, make no reference to this matter, although the point is admitted that job rates have been cut.

Dealing with the objections in the order stated, the cutting of job rates must be taken. There can be no question that the cutting of job rates is entirely wrong as a policy. In any case it is an abuse of power, while, as a matter of business only, it is bad if but because of the reaction which follows rate-cutting and which results in restriction of output in one of its worst forms, this tendency more than counterbalancing any apparent saving shewn by the cutting of job rates. The question, however, is not so much that job rates have been cut as why it was found or thought necessary for them to be cut, and further, as to whether the methods adopted under collective systems will obviate that supposed reason.

In the first place, the cutting of job rates would appear to be due to one or more of the following causes:

A. That an obvious mistake had been made in fixing the rate.

B. That the rates were considered or had been proved to be too high for satisfactory trading.

C. That the employer was greedy.

Where an obvious mistake had been made the British worker is usually found to be sufficiently intelligent and a sportsman to recognize such, and to agree to a correction; but the mistake must be an obvious one.

Dealing with the question of the greedy employer, there is no doubt that, in some cases, rates have been cut without the remotest justification, and that this has served to cause dissatisfaction and annoyance. This, however, reflects an attitude of mind on the part of the man or firm who may be concerned which would operate independently of whatever system of payment might be in use. In the same way there are workers who deliberately malinger, for the purpose of obtaining unnecessarily high job rates, or increases on rates which are already sufficient, but it would be out of place to label either class by its exceptions.

The more serious difficulty arises when job rates are found to be so high as to render the resultant costs greater than the trading conditions will stand. This would appear to infer that either the trading conditions have changed or that the rates were originally fixed on too liberal a basis. In what manner is this more a possibility of one system than another ?

The phase of the question under consideration is one largely of history, and the methods which obtained, while that history was being made, need to be reviewed. Job rates, until comparatively recent years, were based more or less on the time taken, reductions being made sometimes according to the opinion of the foreman, or whoever was fixing the rates, as to whether the time taken was high or not. Thus the practice or the speed of the workers, incidentally of the whole shop, would be reflected in the job rates so set.

Under a collective system what would be the procedure ? The method recommended by advocates of collective systems is to take the existing output as a basis and to increase the wages paid in the same proportion as that by which the output obtained exceeds the " existing " output. Thus the methods advocated for the fixing of collective job rates are precisely similar to those formerly used in fixing individual job rates, and where this policy is adopted it follows that the conditions with which individual systems have been faced will also confront collective systems, and if costs are too high and trading becomes difficult then some remedy must be found either in reduced costs or new productions, or in the closing of the works. These are precisely the circumstances which have attended the use of individual systems when the bases of payment have been unsound, and neither good intentions nor promises can alter the situation. It is the logical outcome of inefficiency, and does not, necessarily, involve or reflect upon the principles underlying the method of payment in use. The methods advocated in connection with the fixing of the basis of remuneration for collective systems are not only unsound economically, but they represent the most retrogressive step which has been publicly recommended with regard to the remuneration of labour during the present generation.

The question must be taken a stage farther, however, before it can be dismissed. If it can be agreed that, under both individual and collective systems, the question of costs being too high can arise, and some remedial action would be necessary, then, from the

purely economic standpoint, further consideration is necessary to ascertain, so far as is possible, if and to what extent the operation of one system is likely to be more satisfactory in this respect than the other.

Let it be presumed—presumption is unavoidable because of the infancy of collective systems—that in each of three works, similarly planned and equipped, manufacturing the same article, a system of payment by results has been introduced; that the output of each works, previously, was approximately the same and that rate of output was taken as the basis of job rates in two cases, while in the third the basis used was the estimated value of the work independently of the rate of output previously given.

In works "A" and "B" an individual system is installed, the basis of job rates in the former being estimated rates of output, in the latter the actual rate of output. In works "C" the collective system is adopted, the basis of payment, as in works "B," being the existing rate of output. Let it be presumed further, that competition exists between the three works for the home as well as for the foreign trade.

It does not appear necessary for the argument to discuss the terms in which the job rates are given, except to reiterate that, with the individual system, as adopted in works "A" and "B," a separate rate is given for each operation, the worker or workers concerned reaping the benefit directly of the results of the additional efforts put forth, while in works "C" a rate is set for the whole works, the individual workers sharing equally, either amount or percentage, accordingly as output has been produced above the basis rate.

In a normal works the objects sought are quick and cheap production, and accordingly as competition is felt so are these objects more assiduously pursued. Thus improvements in methods more or less important are constantly being made; a new jig; an additional multiple tool; a modification in the shape or size of the material used for an individual piece; stampings may be provided in the place of bar material or forgings; fixings may be altered so that two pieces may be machined at a time instead of one; pressings, involving tools, may be used in the place of castings requiring machining; automatic machines may be purchased to replace turret lathes or milling machines or as additional machines. These are but examples of the manner in which workshop methods and production facilities are being continually improved.

What is the effect of such improvements on the general output? Should the respective firms reap any benefit in the shape of reduced labour costs from the increased facilities which they have provided and which enable output to be increased without calling for additional efforts from their workmen? If so, how can this be obtained under the two systems in operation?

The effect of radical alterations to manufacturing conditions is designedly left out of the discussion. When such took place a

modification of the basis rate would be so obviously justified that it could be made without fear that the charge of rate-cutting would be made. What is of some importance is the cumulative effect of what may be termed petty improvements of the kind mentioned.

Under the individual system, when a change is made in the tools or the method used for a given operation, the considerations required are for that operation only. Thus if for a milling operation the fixing and cutters were modified and the modification made enabled two pieces to be milled in the time formerly taken by one and the total time per piece was made up as follows: 1 minute setting—10 minutes cutting, the total time being 11 minutes, then, seeing in such a case cutting time could reasonably be the same for two pieces as for one, the output under the new method would be nearly doubled, the worker being required to perform 1 minute's additional work in the setting of the extra piece. Analyzed, the results would be as follows.

	Milled.	
	One per Setting. Minutes.	Two per Setting. Minutes.
Setting in machine, worker's efforts involved	1	2
Milling—Worker watching. Additional facilities provided by employer	10	10
Total	11	12
Average time each	11	6
Worker's additional effort		9.1 %
Additional output		83.3 %

In this instance it will be noted that the worker under the new conditions would be actively employed 16.6 per cent. of the total time—not working harder—while with liberal allowances for gauging, etc., much less than 50 per cent. of the total time would be occupied. This example is not cited as being general, although it is by no means exceptional, but is worthy of mention because there is a good deal of uninformed opinion to which questions of increased output obtained have been presented as being due entirely to increased effort on the part of the workers and as indicating really sustained and arduous efforts in its achievement. It would be in the nature of a surprise to some others beside the general public to realize the actual percentage of time which, in some industries, is actively involved with either normal or increased output. Of course there are many other improvements made where the increased output obtained shews up differently, although even there the position as regards the efforts required is quite often incorrectly reflected in the results.

In considering the question, sufficient activity on the part of the worker must be assumed to ensure reasonably continuous working. That being the case, improvements in methods and tools call for a change rather than an increase of effort. For example, let an operation be taken which is performed on a sensitive drilling machine. The jig has been improved to make cleaning easier and also to facilitate clamping. No question has been raised about the worker's output which is presumed to be satisfactory. The improvements made to the jig enable the cleaning time to be reduced by a quarter of a minute, and the setting and clamping time by a similar amount, the drilling time being unaffected. The results would be as follows :

	Using old jig.	Using New jig.
	Minutes.	Minutes.
Cleaning - - - - - - -	·5	.25
Setting and clamping - - - -	·5	.25
Drilling - - - - - - - -	1.0	1.0
Total - - - - - - -	2.0	1.5
Increased output - - - - -		$33\frac{1}{3}$ %
Increased effort required - - -		Nil.

The contention is that, theoretically, the manufacturer is entitled to reap the whole of the benefit of improved facilities which he introduces and pays for, because the amount of effort called for is not increased, its direction is changed only ; obversely, where increased efforts, making the work more arduous, result in increased output, the worker is entitled to benefit and in accordance with the system in operation.

It will be seen that under an efficiently organized individual system the conditions under which rates have been given can be known, and that when changes of method are introduced the improvement effected is a matter of direct comparison with that which was previously possible, and job rates can be and are modified without any charge of cutting rates being risked. In this respect the individual system is elastic, and honestly worked would appear to present no special difficulty. Improvements made, with their accompanying justifiably modified job rates, would be reflected in the costs and these would shew progressive reduction, and works "A" and "B" would be able to meet competition with some confidence, knowing that their improving methods could bear immediate fruit in the shape of reduced labour costs as well as in the provision of a broader basis for the distribution of oncosts.

How would these same improvements affect the costs of works "C" who are using a collective system of payment ? Do "C" desire to reap the full benefit of the improved facilities for production which they have been gradually but constantly providing ?

If not, will they not be stagnating their labour costs of production on the basis of the standard existing when their collective system of payment by results was started, relying on the saving in oncosts, which would follow increased production under any system, as their total share? Although some advocates of collective systems preach this, is it a sound business proposition? Can any works management intelligently say, and continue to say, "We will give all the increased wages value of output obtained from the improvements for which we have paid money in the shape of salaries and wages for design and manufacture to our workpeople; the increased output we have made possible we will buy again, and continue so to do for all time."

That is the substance of what is being said in support of collective systems. True, it is not put in these words, more is the pity of it.

Supposing, however, works "C" are not prepared to forgo the value of the savings they have made possible, adjustment of job rates will become necessary; and that adjustment must be made either at the time each improvement is made, or at stated periods, when all improvements would be reviewed.

Either method is possible and not impractical, but to put them into force much the same organization and records are required as with individual systems, but what is more important, the avoidance of adjusting job rates, claimed as a chief feature with collective systems, would not be maintained.

It will be of assistance if the presumption as to works "A," "B," and "C" be taken a stage further. It will probably be agreed that in all works, independently of methods of payment of wages in use, there is a movement of steady improvement, and that, due to these improvements which may be made possible by improved methods, tools or organization, there is a tendency for output to be increased. It is known that such improvements in the course of years have enabled output to be increased by as much as 50 per cent. As a conservative figure, however, it will be presumed that the output in the three works, in the course of two years, has been increased by 20 per cent., this amount to exclude or to be additional to such increases which are the result of extra efforts on the part of workers; these may be represented by any amount up to say 100 per cent., although for purposes of illustration this amount will be taken at 33.3 per cent. on the increased figure.

In the case of works "A," due to the basis of job rates being estimated time and thus being independent of the rate of output existing when the system was inaugurated, it will be presumed that the analytical treatment of the work in the preparation of the estimates enabled improvements to be effected and delays eliminated to such an extent that output was increased by 20 per cent. and the basis of job rates was 16.6 per cent. less than in works "B" and "C." For the purpose of the illustration, it will be presumed that after the job rates were fixed, the output was increased, in each

of the three works, by 20 per cent., due to the gradual improvement in the production facilities; also, that, as a result of the inducement offered by making payment by results, there was a further increase in output of 33.3 per cent. The progress of output and cost would be as shewn below, a week's work being taken as the basis.

Works.	"A"	"B"	"C"
System.	Individual.	Individual.	Collective.
Basis of Job Rate.	Estimated.	Actual Output.	Actual Output.
Units of weekly output—time system	6	6	6
Total weekly wages	£360	£360	£360
Cost per unit	60	60	60
Increased output—result of analytical treatment	20 %	—	—
Units weekly output used for basis of job rate	7.2	6	6
Job rate per unit of output	£50	£60	£60
Percentage increased output—improved facilities	20 %	20 %	20 %
Resultant units weekly output	8.64	7.2	7.2
Job rates modified accordingly	£41.6	£50	—
Extra pay—improved facilities	—	—	£72
Percentage increase due to workers' efforts	33.3 %	33.3 %	33.3 %
Resultant units weekly output—workers' efforts	11.52	9.6	9.6
Extra pay—result of increased effort	£120	£120	£144
Total amount of extra pay due	£120	£120	£216
Total percentage extra pay due	33.3 %	33.3 %	60 %
Time wages cost per unit	31.25	37.5	37.5
Extra pay per unit	10.41	12.5	22.5
Total labour cost per unit	41.66	50	60
Total cost, including oncost as being equal to time wages	72.91	87.5	97.5
Percentage cost "B" and "C" over "A"	—	20 %	33.7%

In the illustrations used no allowance has been made for the extra pay which, as is recommended by the advocates of some collective systems, would be due to all members of staff and to all indirect labour; this of course would increase the amount of oncosts in works "C"; neither has any difference been allowed for as regards the varying results which might be experienced in respect to the different appeal which the two systems may make.

On the shewing made, the operation of the two methods of payment goes to indicate that collective systems are less elastic than individual systems, and that the avoidance of the adjustment of job rates, even when obviously justified, can take place only at the expense of shareholders, in not paying increased dividends, really earned, or at the expense of the works—workers as well as shareholders—in not being able to reflect the savings made possible in reduced selling prices, when by so doing more orders could be induced. In these considerations the interests of the consumer are ignored.

Another objection which has been made to individual systems is that in encouraging the individual worker to produce at his best rate, competition is set up causing jealousy and bad feeling between worker and worker.

This objection, if really deeply rooted, is of serious import, inasmuch as it goes down to the very foundations on which our civilization has been built. The desire to be first, to lead, is one of our oldest natural instincts, it is a wholesome desire and calls for the best that is in human nature, and from it has sprung all that is best in this world ; without that desire, which has almost become a faculty, the human race would be little higher than the beasts of the field. Its elimination could quite well be the beginning of the end of the world's progress. Competition, the desire to excel with its appropriate reward is the very salt of every activity, while its absence is accompanied by such indifference to efficiency as to serve as the most effectual bar to progress known.

What is one of the greatest complaints made regarding our civil and municipal services, where promotion is more a matter of age and seniority than ability ? Why did so many business men who entered the service of the Government as civil servants during the Great War take the first opportunity to get out when the War was over ? Because the moribund atmosphere and absence of incentive made life a burden.

It is unthinkable that any class of man seriously desires the elimination of competition and its rewards, and examination of that evidence which is available supports this view.

The complaint put into plain language appears to be that because under an individual system of payment by results, Bill Smith, who is a skilful and energetic workman, does more work and can earn more money than Jack Jones, who is neither as skilful nor as energetic as Bill Smith, the system which differentiates the reward according to the results is wrong, and because Jack Jones is jealous of the size of Bill Smith's earnings, arrangements must be made for the differences between the two to be split ; Bill Smith to give one half of that difference to Jack Jones as a solatium for his incompetence and lack of energy. It is contended this description is not an exaggeration of the position as stated by advocates of collective systems. The question is, does the position as stated reflect the facts, and, if not, is the remedy proposed the right remedy ?

Under the individual system each is given a rate and the worker or workers on each job take the whole of the extra pay which may be earned ; their skill and efforts are reflected in output, and output is reflected directly in the amount of earnings secured. In principle there appears to be nothing unfair in this, nothing which should upset or annoy any other workman.

Bill Smith and Jack Jones might be followed out to their spare time pursuits. It so happens that they live next to each other and each has a garden. Jack Jones, however, simply revels in gardening while Bill Smith does his in a more or less perfunctory manner and neither hoes nor weeds as much as his neighbour, with the result that Jack Jones' crops are 25 per cent. heavier than those of Bill Smith. Does any one ever think of asking Jones to give one half of his additional crops to Smith so that Smith shall not become jealous, and if this were done would Smith increase his efforts the next season so as to equalize things ?

If the principle that each man should reap as he sows be correct, and we must assume that the average British workman is a sportsman, then the cause of the trouble which is supposed to exist has not been diagnosed, and therefore a remedy cannot be propounded, at any rate intelligently.

Presuming, however, that differences in earnings are the seat of the trouble, and having agreed that inequality of earnings, in so far as they represent, fairly, inequality of ability, is not wrong in principle, the next question appears to be—are earnings unequal because opportunities are unequal. If this be so, there is a case whose importance is of the first magnitude, the cause for which must be sought.

Earlier in the chapter it has been stated that until comparatively recent years the fixing of job rates had been based, more or less, on time taken, and that this would reflect the speed, skill, and energy of the individual worker and his acquaintance with the particular piece of work being done. Thus, in the light of the foregoing, rates so fixed cannot fail to present inequality of opportunities, because inequality of performance is the basis on which all subsequent performances have been remunerated.

Admitting the fault, therefore, in all its gravity, the question to be decided is its relation to the system. Is it a fault, inherent to the system, and thus condemnatory of the same, or is it a weakness of organization which can be remedied, and when remedied, prove to be of material benefit to all concerned ?

In the first place, when rates are based on records of time taken as shewn in earlier chapters, they reflect not only several variable factors but also different variations of those same factors, and represent more or less unknown quantities. To say this is unavoidable is to ignore the trend of present-day practice, and to suggest that the operations of engineering production are immeasurable as to time and uncontrollable as to cost. If this be so then individual systems have received a very heavy blow ; if it be not

so, then the aim obviously ought to be to measure operations so that job rates can be fixed in the light of knowledge and with a reasonable degree of equality of opportunity of earnings assured to the individual worker; then jealousy would not be aroused and a fair measure of contentment would be ensured. That this has been done and with considerable success is known, and the chapters on "production estimating" are written to indicate the methods used.

The point to be made, however, is that, in so far as the complaint that the individual system is the cause of jealousy is seriously and generally made, the remedy is not the abolition of the individual systems and of individual reward and their replacement by collective systems and the levelling of earnings, but rather the correction of the real fault, which is due to weakness of knowledge and of organization, and is bound to be more in evidence, although, perhaps, not so obvious, with the operation of collective than of individual systems.

It is believed that consideration of the argument made will go to shew that with collective systems, industrial efficiency and contentment combined are no more certain than with the operation of individual systems, while the elasticity of individual systems, as compared to collective systems, render them the more desirable methods to use.

So far the argument has been centred around complaints which have been made as to the operation of individual systems, and the supposed desirability of obviating those complaints by abolishing the systems under which they arose. It is necessary, however, to consider the weaknesses, if any, of collective systems, because it is systems as a whole rather than one particular aspect which must be reviewed.

The existence of systems of payment by results at all indicates the tacit recognition that when remuneration is made on a time basis only the results obtained in the shape of output are less than is otherwise possible. Theoretically, therefore, it would appear logical to argue, seeing output in its largest volume is essential, that that system of payment by results which would induce the largest volume of output would be the most desirable to instal and retain. For the purpose of this chapter, the considerations to be made in this respect resolve themselves into an examination of the appeal likely to be made by individual and collective systems respectively and the results of their operation, as shewn in their influence on the number of completed articles turned out.

Taking any works as a separate entity, and assuming normal conditions as regards orders in hand, there are certain possibilities as regards output, and these are affected chiefly by two factors:

A. Workers' skill and energy.

B. Managements' organization and administration.

For the best volume of output to be obtained it is necessary not only for the workers to be efficient, as individuals, but also that managements' organization shall be equally efficient, and that the

best efforts of the workers shall be so co-ordinated and utilized that the work done will ensure individual pieces being finished in the right quantities and of the requisite quality to enable the completed article to be produced in a minimum time.

To pay the workers in accordance with the results obtained when these are the direct outcome of their efforts on individual jobs is a fairly straightforward proposition and does not appear to violate any principle, in fact from the point of view of principle it is difficult to justify any other course.

The worker is generally understood to receive and to carry out instructions, to do that work given him in such quantities and to those standards which may be laid down by the management through their representatives from time to time. He is not given authority nor does he carry responsibility, and, theoretically, may be held to be indifferent as to whether the instructions given are correct or not; moreover, he is not likely to have access to that technical and other information which would enable him to form suitable judgments on the various matters which go to decide policy. The more the worker's position and opportunities are considered, the more restricted does his scope appear to be, outside that of the application of his own skill and energy to the tasks assigned to him.

It is claimed by believers in collective systems that one of the great advantages of such systems is their helpful influence on organization; it has been said that "organization is improved beyond belief." It would be futile to contend this claim; such a result is obvious and is common to the operation of all systems of payment by results, when they are suitably organized and administered; one might go further and say that it is due to this influence, with its subsequent improved opportunities for increased production, that payment by results has been so abused, being used out of its proper sphere, and job rates—costs—having been stabilized on too high a basis, has led to the cutting of these same rates. (See Chapter I.)

It is not argued that the individual worker could not be of assistance in spheres other than those of the tasks assigned to him; it is known that in many cases he has the capacity and will so to do, and it is desirable that employers should welcome, take advantage of, and make suitable remuneration for any useful suggestion which may be put forward; but, inasmuch as the worker is paid wages because he is expected to produce, it is contended, logically and in equity, that his remuneration, when payment by results is involved, should be based on his success as a worker under the conditions of his job rate and not be affected by the efficiency or otherwise of other workers, management or organization, for which he is in no way responsible; neither should it be linked up with his ability to organize, for which he was not engaged.

Organization is primarily the function of management, and, as argued in other chapters, this should be made efficient before payment by results is introduced, so that job rates may be based

on efficient working, or at least on a condition of things which makes efficiency possible; but under any circumstances, to put forward to workers the possibility of additional earnings, which embodies as one of its chief requirements the improvement of organization—making management efficient and effective—appears to be a prostitution of payment by results of the worst kind, and an acknowledgment of incapacity on the part of management which requires attention more urgently than does any method of remuneration or workers' energies.

There is one further aspect of the question, and that is the respective appeal of the two systems. Will the individual worker be induced, by a collective system and a share in the pool, to attempt as much as though he were working alone and controlled entirely the factors which could affect the amount of his earnings?

In engineering circles the time rates usually paid are known as district rates and are rates agreed upon by representatives of employers and of the workers. By the workers, this rate is looked upon as the minimum; by employers it is treated almost as the maximum. Does this flat rate give satisfaction to the individual worker? Does the more efficient worker put the supposed trade union principle into practice, that difference in ability to produce should not be reflected in wages. No; the tendency is for the output of the quick worker to be slowed down to that of the average man on the grounds that seeing he is not paid more than the others there is no reason why he should produce more. In a negative manner, the individual worker recognizes the principle of payment by results—production according to payment and on the individual basis. The quick capable worker is frankly dissatisfied with the flat rate and passively protests by restricting his output.

Will a collective system by offering a reward, however diluted, overcome that objection? Reverting to Bill Smith and Jack Jones as gardeners; will Bill Smith be induced to become a good and successful gardener more by his crops reflecting the results of his own labours or because Jack Jones is going to make up to him the difference between the amount of their respective crops? The question does not appear to admit of much argument and experience goes to bear this out.

Instances are known where the use of the collective principle of payment has been objected to on this score; where dissatisfaction has been expressed with the flat rate of remuneration in precisely the same manner as that which has been experienced with the flat time rate. A somewhat significant example can be cited. A collective system had been in use with fitters for some time when dissatisfaction arose over the question of the division of the savings made, and the result was the system was voluntarily changed for one embracing the individual principle. The almost immediate result was an increase of output of nearly 50 per cent. which absorbed all the available material, and by giving 3 weeks output in 2 weeks, the supply of parts not being forthcoming at

that rate, no output was shewn for the third week, the charge being made that the introduction of the individual system had stopped output. It had, by overtaking the supply, and incidentally it was shewn that under the collective system too many men were employed for the work available.

It is not at all improbable that if a true opinion could be obtained as to the manner in which the two systems are looked upon by the workers, the opinions given would automatically divide them into two classes—the competent and energetic and the incompetent or indolent. The question is an important one and cannot be left in the hands of men whose chief qualification to speak is that they have been associated with works that have been badly managed; that is similar to the case of the woman whose knowledge of babies was profound because she had buried so many. Again knowledge and analysis must be the basis.

In the advocacy of collective systems much reference is made to the advantage of what is termed the team spirit, and football teams are referred to as embodying the spirit which is required in the workshops. It would be wrong to decry or to try to belittle the team spirit, but it is equally wrong to attempt to deceive employers or workers by recommending something which has no logical application. Inasmuch as the team spirit to be present requires good-will, the team spirit is to be desired, but the very nature of engineering manufacture and organization is the direct negative of the conditions necessary for team work. Team work suggests combination, engineering manufacture is the carrying out of individual instructions.

Once the football is in play each player does that which he thinks is best calculated to help his team to get the ball through the goal of the opposing team, and a goal is a definite possibility which may be achieved at any minute. In his allotted position each player works largely without instructions. If, in engineering manufacture, a number of men were given, say, an engine to make complete, and their activities could be as free from control as are those of footballers, the team spirit would be a distinct advantage; in fact, without it the result would be of the poorest kind, although with it success would not be assured. When, however, each man is given a definite task to perform, the responsibility for its being the right one not being his, and the influence of which on the finished product is not immediately obvious—many finished parts are sent to stores and remain there sometimes for months—then to talk of the team spirit seems as illogical as it is to suggest that the cowman, the shepherd and the ploughman are the farmer's team, or that the duties of the ploughman and the reaper are such that the team spirit is possible. Good-will is desirable always, but good-will is possible without team conditions being in evidence, and, when definite and independent tasks are assigned, when a man is told, as it were, to kick the ball at a stated time in a given direction, good-will will be shewn by that ball being kicked just as far and as

direct as his skill allows him to do, without the team spirit having any influence at all. Success in engineering manufacture requires management rather than combination, although good-will is necessary with either.

The appeal to the individual as such is direct and is more likely to be effective than the appeal to the individual as one of a crowd. The latter might be said to be of a tangential character, and, if only because the efforts of all concerned are pooled, and, therefore, appear individually to be of proportionately less value to the whole, the average results so far as individual performances are concerned are likely to be less than those which would be obtained from an individual system.

A practice which has been in use in connection with some collective and individual systems is that of including the staff employees in the participation of the extra pay. This has certain decided advantages, but is a question not necessarily linked up with the use of either the individual or the collective principle of payment, and is discussed in Chapter IV.

One difficulty which must always be felt with collective systems is that of productions which are entirely new, and for which, accordingly, there is no record of output. In some works it is by no means uncommon to find that these conditions predominate, and, excepting an estimate has been prepared which can be used as the basis of a collective job rate, the job rate given must be "guestimated" (guessed), and embody serious risks of being either high or low. In a similar connection, where the work carried out is in the nature of special contracts, particularly where large units are involved, output is likely to fluctuate. True, the law of averages may apply when the periods reviewed are of sufficient length, but long periods between payment tend to reduce the value of the appeal and thus to defeat the aim underlying the use of the system.

In a review of the position, it appears that the grounds on which collective systems have been recommended are largely that under individual systems jealousy has existed between worker and worker over the size of their respective earnings, and that job rates have been cut. Because of this it is argued that individual systems stand condemned and that they could be satisfactorily replaced by collective systems. So far as logic and experience go the case is by no means made out. That jealousies have existed as has been contended is correct, but the reason has been unequal opportunities due to the faulty method of fixing rates rather than to any inherent weakness of individual systems, or to the supposed pettiness of the minds of the workers. That job rates have been cut cannot be denied, but the possibilities are not materially different in principle under either system. True, it would be more difficult to cut a rate under a collective system, and if rate-cutting were a matter entirely of greed on the part of employers much importance would be attached to this feature, but seeing economic considerations—competition—have been and will continue to be, to a great

extent, the governing factor in this connection, the position will be much the same under one system as another.

A works can be kept running only so long as there are orders in the books; orders can be obtained most readily when the prices quoted are competitive, and if competitive prices cannot be quoted then, whatever system is in use, the manufacturer will be faced with the necessity of reducing his costs, and whether relief is to be sought by improvements to methods or in alteration to design, a collective system is likely to present the most difficult means of obtaining it.

Difficulty of adjustment of job rates, however, is not the deciding factor; it is rather that the unwieldiness of such schemes from the standpoint of defining efficient output, and therefore of pursuing efficient costs, is such that these are not likely to be seriously attempted. The policy followed under collective systems can hardly be indicative of anything higher than a desire for improvement, and this has proved to be quite inadequate for present-day needs; not only so, the desire for improvement is the rock on which individual systems have struck, and on which any other system is likely to strike when it is based on lack of knowledge as to what is really possible.

CHAPTER VII

INDIVIDUAL SYSTEMS COMPARED

It has been shewn in Chapter VI. that the description of a system of payment by results as "individual" or "collective" reflects the treatment of jobs at least as much as it does that of the individual worker's efforts; at the same time it is the effect on the individual which counts and must be considered. The difference of the appeal made by the various individual systems is at certain stages most marked, and even as with the considerations which are necessary when deciding as to whether the individual or the collective principle shall be used, so is it necessary for the probable appeal to the individual to be considered, when deciding as to which of the various individual systems extant shall be put into use.

Really there are but two main principles embodied in the various systems, although these are put into force in more than one form and with different conditions. These may be described as follows, together with particulars of the systems in common use in this country embodying the respective principle.

1. The job rate represents the whole of the remuneration offered.

A. Pure piece-work.

2. The job rate is effective only when the value of the output, in the terms of that rate, is in excess of the time taken or of the workers' time wages.

B. Piece-work with guaranteed time wage.
C. Premium System—Rowan.
D. Premium System—Halsey-Weir—50 %.
E. Premium System—Halsey—$33\frac{1}{3}$ %.

Opinions as to the relative merits of these four systems vary considerably, and in practice the systems are to be found in operation under widely different conditions, while the reasons given for the adoption of any one system will often be found to be contradictory in character.

At one time the two methods of remuneration in common use were the time system and pure piece-work, and in some industries the latter is predominant to-day. Whatever may be the basis of job rates, however, the system of pure piece-work embodies to a high degree those conditions which make the fixing and working of economical job rates exceedingly difficult.

The supposed advantage of the pure piece-work system to the manufacturer is that he knows just exactly what his labour costs will be. This undoubtedly is to be desired, and is an advantage not to be lost sight of; at the same time, while to know one's actual labour costs is eminently desirable, to ensure economic costs is of even greater importance. Under a pure piece-work system the manufacturer is able to offer as a job rate that sum which, at that time, with the cost of material and oncosts added, will enable him to sell at a profit. His labour costs thus become the most stable item of the three; by it he is safeguarded against the incompetence of his workers; against their inability to work at the normal rate, whether due to ill-health or to other reasons; against payment for idle time due to breakdowns; he is also safeguarded, to some extent, from paying for loss of output which may be due to weaknesses of organization for which he is primarily responsible.

On the other hand, there is a complete absence of safeguards for the worker. If there be work to be done, the successful applicant is afforded the opportunity of doing that work at an agreed figure; whether or not the contract proves to be a profitable one depends upon one or both of the following factors: that the job rate is sufficient for the work to be done; that the applicant is sufficiently skilled.

This is making a purely commercial bargain, and, theoretically, is sound in principle; the individual worker is given precisely the same conditions as are given in the commercial world to the manufacturer for whom he is working, by the result of which he must abide. Unfortunately, there are many ideas which are right in theory but are not always easy to carry through efficiently into practice.

In the first place, when a manufacturer desires a contract, he obtains particulars of the work to be done, and if these appear to be of a straightforward or easily controllable character, he submits a tender in which he offers for a stated sum to carry out the work required. That tender is based on an estimate in which is included, amongst other items, an allowance to cover contingencies. If the work appear to present any difficulties, the cost of surmounting which is not readily estimated, either the contingency allowance is increased or the manufacturer may decline to tender on any but a "time and lime" basis, *i.e.* cost plus profit.

Actually at one time it was the practice to put industrial operations out to tender amongst individual workmen, resulting, quite often, in one workman employing and paying other workmen to carry out the work for which he had contracted. This practice has now fallen very much into disuse, having satisfied neither manufacturer nor worker; in fact, with regard to the latter the "sub-contractor" was usually considered to be a more tyrannical employer than the manufacturer himself proved to be. Under this system much discontent existed among the workers who were thus engaged, while the contingency factor included was often such that the profits of the sub-contractor were entirely out of proportion to his responsibilities.

Experience then of the workers carrying out industrial operations on purely commercial lines on a large scale has not proved successful or satisfactory to either party, and the individual system still reigns. There is a difference, however, between the worker working on pure piece-work and the manufacturer carrying out a contract obtained as a result of a tender submitted, and this is that the manufacturer not only states his terms in his tender to his prospective customer, but, as the worker's prospective customer, he wishes to state the terms on which the worker's contract shall be carried out. In so doing a clashing of interests is bound to take place, and this shews up in various ways.

Remembering that man works not because he likes work but because he must procure the wherewithal to buy the food and clothing necessary to sustain life, then his first aim, when job rates are being fixed—and these job rates comprise the whole of his opportunities for earning wages—is to make sure that the return thus made possible shall be such as to enable food and clothing, etc., to be procured in sufficient quantity to keep himself and, possibly, his wife and children in reasonable comfort. Unlike the manufacturer who, in dealing with the results of the work of many men, can average good and bad results together, the individual worker on pure piece-work feels called upon to make sure that each week such an amount of earnings will be available which will enable him to meet his various commitments. This makes it necessary, or at least advisable, that each job handled shall make possible this average amount of earnings; and so soon as a worker realizes that his earnings are to be entirely dependent upon the amount of work satisfactorily done, and at a given rate, he, not illogically or unfairly, determines that, recognized or not, job rates shall include a safety factor which shall be sufficient to cover all contingencies. He may thus be fighting not so much for an easy time as to ensure provision for a sufficiency of food. The job rate offered by the manufacturer is likely, if an allowance for contingencies be included at all, to be less than the worker thinks sufficient, and the result is a battle of interests and wits in which the worker is quite often successful. The resultant job rates, consequently, are most likely to be fixed on a basis which is higher than need be, due to the wide range of the contingencies provided for. An actual experience will be of interest, and will illustrate the influence of the system on job rates.

In a shipyard department pure piece-work was introduced, the method of remuneration previously employed having been that of time. Some opposition and considerable difficulty was experienced, the job rates offered being held to be such as to render it impossible in some instances for any man, and in others for slow or less skilled men, to make sure of earning the time rate of wages, and the line taken, as a matter of principle, was that no man would accept a job rate excepting the slowest man in the shop felt assured he could earn at least time wages. The result of this attitude, on job rates,

can be imagined, and realizing the permanent effect thereon of continuing on this basis, it was decided to guarantee time wages, and immediately the strenuous fight for high rates was relaxed, and jobs, which for the rates offered were considered to be impossible, were attempted, and made "to pay." There is no doubt that after the time wages were guaranteed output was obtained at less cost than would have been the case if the principle of pure piece-work had been adhered to, and although incompetent and indolent workers are to be met with and guarded against, this is a matter which can and should be dealt with through other channels.

Those systems which fall in Group 2 are really premium systems, inasmuch as the time wage is guaranteed and the extra pay earned is really a premium equal or proportional to that amount by which the value of the work done in a given time exceeds, at the job rate operating, the time wages value of the hours spent. Strictly speaking, where time wages are guaranteed there can be no piece-work system, and references to the system previously known as such will be made under the heading of the "Plain Premium" (100 %) system. Thus with a guaranteed time rate it is necessary always to compare the earnings as shewn by the number done and the job rate with those due according to the time worked, and, in either case, the greater amount must be paid. The guaranteeing of time wages has been the almost universal practice in engineering workshops since the principle was agreed upon by the Engineering Employers' Federation and the Amalgamated Society of Engineers in 1907.

Prior to this agreement much discontent existed over the operation of piece-work systems; in many cases undue advantage of the workers had been taken by manufacturers in forcing the acceptance or the reduction of job rates which were so low that it was made exceedingly difficult, and sometimes impossible, for time wages to be earned even when the workers contended they were working at "piece-work speed."

In discussing the various systems it is well to keep in mind the objects for which they were devised and also the conditions which had to be met. The piece-work system had proved to be a failure in two directions: (1) costs were too high because job rates were at fault; (2) the correction of the fault by reducing the job rate caused discontent and encouraged restriction of output. It being known that more work could be done in a given time, and that the cost per piece could be much reduced, the problem was how to obtain these somewhat conflicting objects without upsetting the workers. By them, a reduction in job rates was looked upon as prejudicing the possibility of earning a fair living, their fears in this direction being one of the causes of the job rates being high.

It was with the object of avoiding these difficulties that what is known as the premium systems were introduced, and, while these have had a somewhat chequered career, yet under the circumstances the difficulties were really well met, and, possibly, from one point of view were met best by those systems which appear to-day to be

least satisfactory. Time wages being guaranteed so that the fear of not receiving a fair wage was to some extent removed, and the value of the time saved being shared between worker and manufacturer, encouraged the worker to work more quickly in order to save time, the manufacturer reaping the benefit in reduced costs.

If it could have been taken that the worker's energy and ability to produce were the only effective factors in production, the arrangements then made could have been regarded as fair and profitable in a high degree so far as the worker himself was concerned. Then he would have been rewarded for correcting his own shortcomings, and the less satisfactory his output had been the greater would have been his reward. It could be held that, in these circumstances, that system was most wisely devised in which the reducing factor was the more effective as the proportion of time saved was increased.

Of course, it is known that other factors are at least as important as are the workers' energies, although it would appear that this fact was not sufficiently realized in those days, but the conditions to be met now are much different. The job rates of to-day are not based on the rate at which output has been obtained ; they must provide the opportunity to earn " time and a third," a distinction with a greater difference than may appear on the surface.

Nothing was laid down in the early days as to the amount of earnings which a man should be able to make—such a provision was not called for—but 25 per cent. became gradually to be looked upon as representing the happy medium. It may be that when this amount of earnings was exceeded, reductions in job rates were found to take place ; but whatever the reason this amount became the commonly accepted standard until the war period. In considering the systems which have been so long in use it is necessary to remember that conditions have changed, and attention is necessary to ascertain their fitness for present use.

The premium systems were originated in America, their chief feature being that the time rates of wages were guaranteed, irrespective of whether the job rate was exceeded or not, and that the time saved was divided in a prearranged manner between the manufacturer and the worker, leaving the job rate intact. There are two main systems in common use, the " Halsey," introduced by Mr. F. A. Halsey in the year 1890, and the " Rowan," introduced by Mr. David Rowan of Glasgow in 1898, the originator of the only British system in general use. The two systems vary chiefly in the method of sharing the savings made. Mr. Halsey used a flat percentage, preferably a small one, and that usually associated with his name is $33\frac{1}{3}$ per cent. A variation of this is known as the " Halsey-Weir," with which the savings made are equally shared ; this system is usually referred to as the " Halsey-Weir 50 % " system. Under the Rowan system the savings made are shared on a differential plan, the workers' share being lowest when the time saved is the highest. The rule is that the extra pay earned bears the same relation to the time taken that the time saved bears to the job rate.

It will be of assistance in the consideration of the value of the different systems if a hypothetical case be taken for purposes of illustration. Thus in the interest of simplicity, and seeing many people prefer to think in terms of money rather than time, the rate per hour will be taken as one shilling, and figures relating to hours can then be read as shillings also, if desired. The extra pay to be provided for will be 33⅓ per cent. (see Engineering Trades Union Agreement, 1st April, 1919), and the time in which it is estimated the job should be done will be 60 hours.

Now, inasmuch as under the different systems the proportion of the time or money saved which is paid to the worker is varied, it follows that the addition which must be made to the estimated time to make the job rate appropriate to the system in use must vary likewise. Thus, where 100 per cent. or the whole of the saving is paid to the worker, the amount which falls to be added to the estimated time is 33⅓ per cent. only; and, in the case of the plain premium system, to obtain the job rate for the illustration taken, 20 hours should be added to the 60 hours estimated as the time the job should take, the resultant job rate being 80 hours or, if desired, 80 shillings.

If one of the sharing systems were in use, however, under which a proportion only of the saving made is paid to the worker, the appropriate job rate would need to be greater, accordingly as the size of the share to be paid to the worker at the point where the job is presumed to be done in the estimated time is large or small. This is a feature which is often quite lost sight of by manufacturers and workers alike, albeit for different reasons, and, as will be shewn later, opportunities for earning extra pay are afforded, even after the total estimated labour cost of the job has been exceeded. Thus, so far as the slower workers are concerned, more extended opportunities for earning extra pay are offered under the systems where the savings are shared than others.

Under the Rowan system, the share of the savings made, paid to the workers, is a variable one, and the arrangements are such that when the proportion of the job rates saved is lowest, the proportion of such savings paid to the workers is highest; while, on the contrary, when the proportion of the job rate saved is the highest the workers are paid the smallest proportion of same. At the same time, it must not be lost sight of that although the proportion of the savings paid to the workers, under this system, is reduced as the percentage of the job rate saved is increased, the actual hourly earnings are constantly being increased. Really, the system may be best described as a differential premium system where the premiums may vary from 0 to 99 per cent.

Then, on the assumption that extra pay of 33⅓ per cent. is to be provided for, that same percentage of the job rate must be available for that purpose, and for 33⅓ per cent. extra pay to be made possible on a job which it is estimated should be done in 60 hours, the job rate must be such that one-third taken from it will leave the esti-

mated time. It thus falls that to the estimated time 50 per cent. must be added to give the rate required. For the job in question, the job rate would be 60 hours estimated time plus 30 hours, representing 50 per cent. of the estimated time, making a total of

PLAIN PREMIUM SYSTEM (100 %).
(Piece-work System with Guaranteed Time Wage).
Diagram Shewing
Hours Taken—Time Wages—Extra Pay—Actual Cost.
For Different Outputs against Estimated Cost.
Estimated Rate of Earnings—Time and a Third.

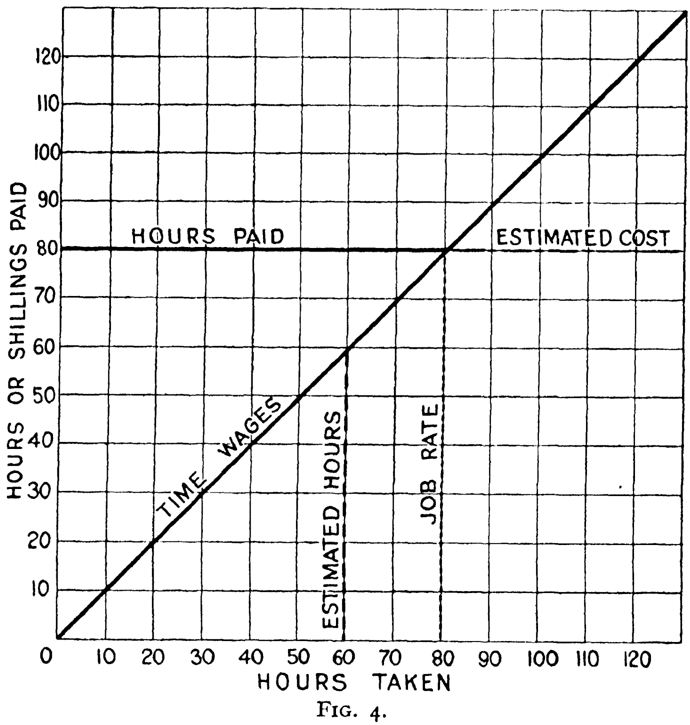


FIG. 4.

Under the Plain Premium System the value of the whole of the time or of the money saved is paid to the worker, consequently there is no reduction in labour cost however large a proportion of the job rate may be saved. The job rate is equal to the estimated time plus one third ; thus the estimated cost and the job rate are equal, and consequently, no extra pay can be earned once the estimated cost has been reached. Under this system all the advantages of the piece-work and the sharing premium systems are secured to the workers, while the employer must bear any additional cost which is the consequence of low output. For the Plain Premium System to be used and for economical costs to be ensured, a higher percentage of efficiency is required in all directions than with any other system. This system is popular with workers because of the high earnings possible under it.

ROWAN PREMIUM SYSTEM.
Diagram Shewing
Hours Taken—Time Wages—Extra Pay—Actual Cost.
For Different Outputs against Estimated Cost.
Estimated Rate of Earnings—Time and a Third.

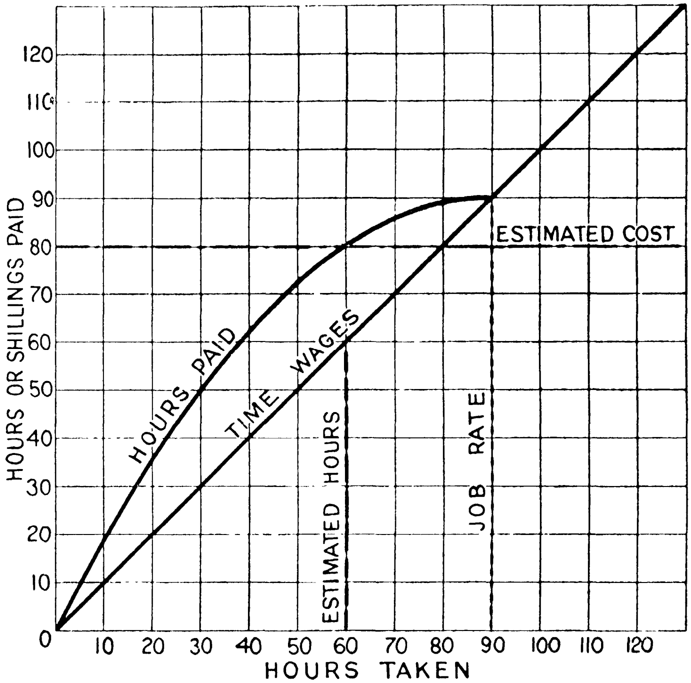


FIG. 5.

The Rowan System is more complicated to work than any other system in common use. For the conditions which it was devised to meet, however, it is probably the only system which had a logical feature and that was that the extra pay due should bear the same relation to the time taken as the time saved bore to the job rate. The calculations necessary to compute the extra pay due are less simple than those of the Halsey group, and this, together with the comparatively drastic effect of its reducing factor, has militated somewhat against its use. Under the conditions obtaining to-day its one time logical feature has disappeared and to the abnormally clever worker the results can be quite unsatisfactory, as will be evident by the small return made to the worker for really large outputs. For a class of work where output cannot be even approximately measured, the use of the Rowan System will be attended by the least risk, because under it, it is impossible for double wages to be earned. The job rate is found by adding 50 per cent. to the estimated time.

$$\text{The extra pay earned} = \frac{\text{time taken} \times \text{time saved}}{\text{job rate}}.$$

When the value of time taken equals the estimated cost, extra pay is still due equal to 8.8 hours time wages, increasing the actual cost above that estimated by 11.1 per cent. The system cannot be said to be popular with the workers nor is it inducive of the best volume of output.

90 hours. Assuming the job to be done in 60 hours, the extra pay calculation will be as follows :

$$\text{Extra pay} = \frac{60 \times 30}{90} = 20 \text{ hours.}$$

HALSEY PREMIUM SYSTEM ($33\frac{1}{3}$%).
Diagram Shewing
Hours Taken—Time Wages—Extra Pay—Actual Cost.
For Different Outputs against Estimated Cost.
Estimated Rate of Earnings—Time and a Third.

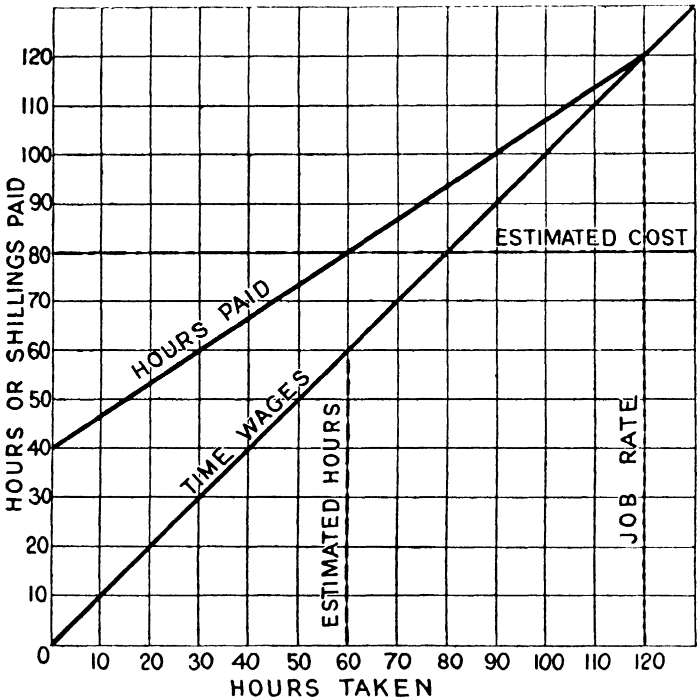


FIG. 6.

Under the Halsey $33\frac{1}{3}$ % system the time saved is shared as follows :
Two thirds to the employer.
One third to the worker.

To enable extra pay to be earned equal to one third of the time wages, it is necessary to double the estimated time in order to arrive at the appropriate job rate. As a consequence, opportunities for earning extra pay are continued for a more extended period than under any other system. When the estimated cost has been reached, *i.e.* 80 hours have been taken, 40 hours will be shewn as saved, the resultant extra pay being 13.3 hours and the actual cost will be increased thereby, above the estimated cost, by 16.6 per cent. Because of the drastic reducing factor this system is not likely to be popular, although for workers of less than average ability it is the most generous because of the extended opportunities for earning extra pay. The system is simple to work, as is also the calculation of the extra pay due.

Under the Halsey system it is usually understood that $33\frac{1}{3}$ per cent. of the time saved is paid as a premium, although Mr. Halsey appears to have specified a flat premium per hour saved rather than any special percentage, and was in favour of a low percentage rather

HALSEY-WEIR PREMIUM SYSTEM (50 %).

Diagram Shewing

Hours Taken—Time Wages—Extra Pay—Actual Cost.

For Different Outputs against Estimated Cost.

Estimated Rate of Earnings—Time and a Third.

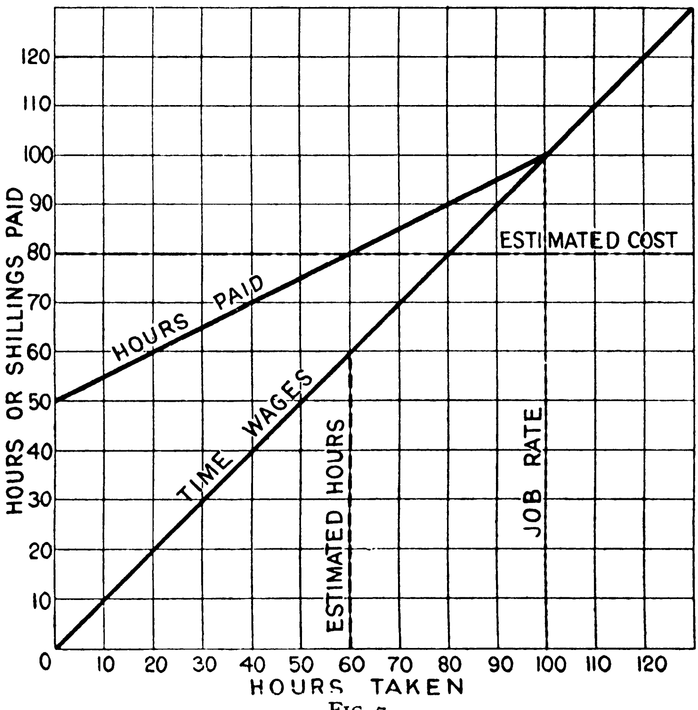


FIG 7.

Under the Halsey-Weir System the time saved is shared equally between the employer and the worker. To enable extra pay to be earned, equal to one third of the time wages paid, it is necessary to add 66.6 per cent. to the estimated time. Under this system, opportunities for earning extra pay are continued after the estimated cost has been exceeded. This is one of the features of sharing systems; a reducing cost as the time taken is less than that estimated; an increasing cost, when the estimated time is exceeded up to the point when the job rate is reached. Thus when the estimated cost has been reached in the form of time wages, that is, 80 hours taken, extra pay equal to 10 hours time wages is due by which the cost is increased to $12\frac{1}{2}$ per cent. above the amount estimated. The Halsey-Weir System is the most popular of all the sharing systems in common use and probably induces the best output. The simplicity with which the extra pay due is calculated is one of its recommendations—one half of the time saved.

than a high one. It is convenient to take $33\frac{1}{3}$ per cent. for purposes of illustration, and the influence of this low percentage on the appropriate job rate is decidedly interesting. The amount of extra pay due under this system and the workers' share of the savings is obtained by dividing the time saved by three.

EXTRA PAY. BASIS OF JOB RATES—I.

Diagram Shewing

The Extra Pay Due when the Basis of Job Rates is Time Taken.

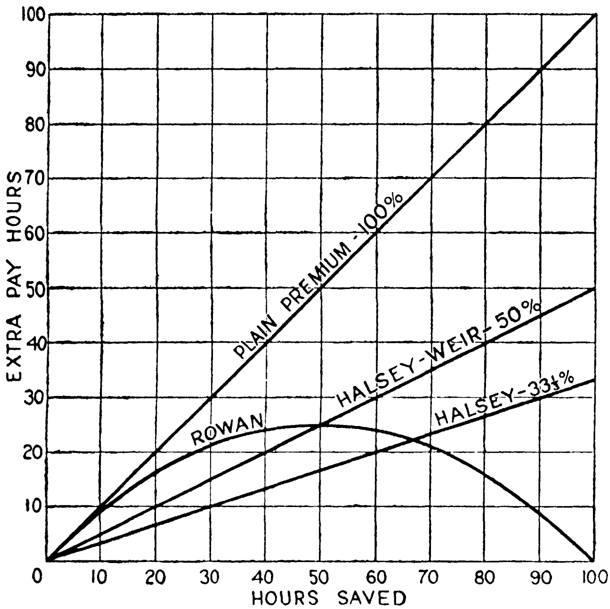


FIG. 8.

When job rates are based on time taken, the starting-point of extra pay is bound to be time saved, and the extra pay under all systems radiates from the zero point of no savings, at which point all the systems referred to are equal. Under the Plain Premium System (the piece-work system with a guaranteed time rate) the whole of the savings are paid to the workers; under the Halsey and Halsey-Weir systems, arbitrary divisions are made, while under the Rowan system the worker is paid a percentage on the time taken equal to that percentage of the job rate which is saved. The more generous payments under the Rowan System when not more than one half the time has been saved will be noted, as also the smaller proportion of same when more than one half has been saved.

Then to provide a job rate which will enable extra pay of $33\frac{1}{3}$ per cent. to be earned, an amount must be added to the estimated time which will be three times that of the premium, and this means that the job rate under this system must be just twice that of the estimated time. Thus, for a job estimated to take 60 hours, the job

rate would be 120 hours, and the extra pay due will be found to be 20 hours:

$$\text{Extra pay} = \frac{(120-60)}{3} = 20 \text{ hours.}$$

The Halsey-Weir system is really the Halsey system, but with a higher percentage of the saving made paid as a premium than that

EXTRA PAY. BASIS OF JOB RATES—II.

Diagram Shewing

The Extra Pay Due when the Basis of Job Rates is Estimated Time and Earnings of "Time and a Third" are provided for.

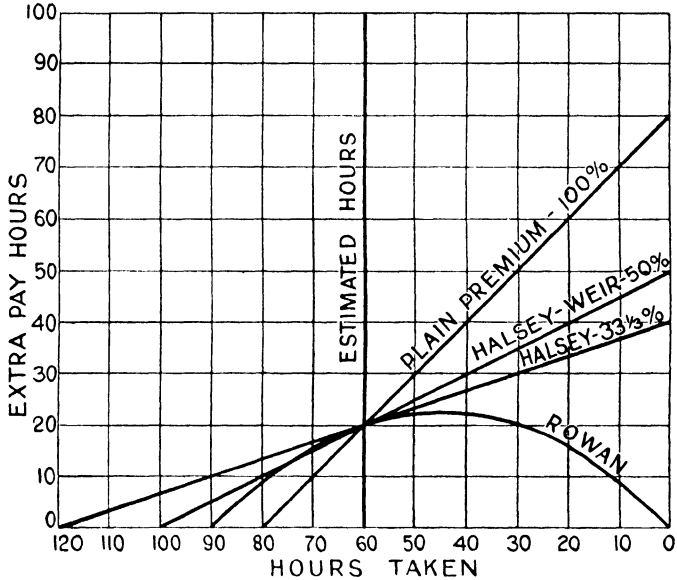


FIG. 9.

The difference between basing job rates on time taken and on estimated time with the provision of a definite amount of extra pay affects all the systems in common use.

The point at which all are equal is estimated time, but the smaller the share of the savings paid to the worker the larger does the job rate need to be. The point at which extra pay starts indicates the job rate appropriate to the system, and these will be seen to vary considerably, those required under the Halsey and Halsey-Weir systems being the highest. Seeing the basis of job rates is supposed to be rate of output possible of attainment, the wide differences in the amounts of extra pay provided for is a matter of some interest, as also is the fact that under the sharing systems extra pay is provided for after the estimated cost has been exceeded.

advocated by Halsey. The introduction of the payment of an amount equal to 50 per cent. of the time saved is usually associated with the firm of Messrs. G. & J. Weir of Glasgow, hence the name. Like that of the Halsey $33\frac{1}{3}$ per cent. system, the calculation of

the amount of extra pay earned is of the simplest, the time saved being divisible by two.

To provide the requisite job rate, seeing $33\frac{1}{3}$ per cent. is to be provided for extra pay and that amount is to be equal to one-half of the time saved, it follows that two-thirds or 66.6 per cent. must be added to the estimated time. This, for a job estimated to take 60 hours, would mean an addition of 40 hours, making a job rate of 100 hours. Then, with the job done in 60 hours, the time saved will be 40 hours—one-half of which, 20 hours, will be the amount due for extra pay.

$$\text{Extra pay} = \frac{(100-60)}{2} = 20 \text{ hours.}$$

It has been a common practice to compare these various systems, as to the amount of extra pay provided for, from the standpoint of equal job rates, and somewhat erroneous opinions are held by the respective advocates of the Halsey-Weir and the Rowan systems. To compare these two systems from the standpoint of equal job rates is correct only when the basis of the job rates is the actual time taken; but when a specified rate of earnings has to be provided for, or when job rates are based on estimated times, the comparison must be made from the standpoint of the appropriate job rates, each of which is different. Diagrams are shewn on pages 94 and 95, which illustrate the difference made by the changes referred to. From these it will be seen that whereas formerly the question was one solely of time saved, all savings radiating from the job rate—the time previously taken—it is now one of estimate and time taken, the common centre being the estimated time, not the job rate.

Thus it will be seen that for each different method of sharing the savings made, if equal opportunities are to be afforded for the earning of extra pay at some given point, a different job rate is required, and that the smaller the percentage of the savings made that is paid to the worker, the larger the job rate needs to be. Although the practice of comparing the merits of the different systems from the standpoint of equal job rates infers the basing of such job rates on some standard other than that of estimate, this use of an estimate as a basis can hardly be put on one side because of the agreement made in 1919 between the Engineering Employers' Federation and the Amalgamated Engineering Union, in which it is laid down that the job rates must be such that a workman of average ability should be able to make time and a third. At the same time, the use of an estimated figure in this connection is an indication of a change of practice and policy which needs to be given serious attention.

The latter is an entirely different kind of proposition from that of saying to a worker that, if he can reduce the average time taken on a job which has usually taken him say 100 hours to perform, he shall be paid the equivalent of the whole or a portion of the value of the time saved. When this was more or less the practice, there

was no question of a standard of earnings involved; the only standards existing were those of previous performance and cost, and any question which was raised was rather as to the liberality of the system concerned, the apportionment of the saving rather than its amount, some increase of earnings being almost bound to follow. A system, designed for one set of conditions, however, might be quite unsuitable for another, and seeing the basis originally used was uncertain, and so far as actual known value of the work involved was concerned, was uncertain to a high degree, and also that no standard was laid down as to the amount of earnings which should be made possible, the question as to what the job rate is to be to-day is much different than formerly, and systems designed to meet those conditions—and which may have done so reasonably satisfactorily—may require remodelling to meet the conditions now obtaining.

In the examination of the various systems described, it will have been noted, probably, that one of the chief features is either the presence or the absence of safeguards; safeguards for the manufacturer against paying too much for his production; safeguards for the worker in respect to a minimum wage; against job rates being arbitrarily cut, by the introduction of methods of sharing the savings made, ensuring, thereby, reductions in the wages cost of production. Each of these, in broad principle, may be desirable, but it is most noticeable that each attempt at safeguarding any interest carries with it its own counterbalancing influences.

With pure piece-work, for example, while it can be known beforehand what a piece of work will cost for labour, the safeguard is but a superficial one because, in the desire to make sure of a sufficiently large weekly earning, the job rates sought and often obtained are higher than the work to be done actually justifies. The effect of such a safeguard is merely to prevent the job cost from rising above the job rate, there being an ever-present tendency to make the job rate and, therefore, production cost too high, and, excepting job rates are reduced, cost must remain permanently high.

With the plain premium system the worker is safeguarded as far as his normal time rate of wages is concerned by this being guaranteed, but, owing to the fact that no reduction in direct labour costs can be secured, costs of production, apart from the saving which oncosts should shew, must remain constant. This has led, with or without justification, to the reduction of job rates, and also to considerable discontent. Under this system, as with all systems where the time rate of wages is guaranteed, the wages cost of production can rise above the normal job rates. (See Fig. No. 4, page 90.)

Under those systems where the savings made are shared the labour costs are automatically reduced as the output is increased, and it will be obvious that the return to the individual worker must, at some stage, be less than would be the case under the pure piece-work or the plain premium systems, always excluding the operation

of the guaranteed time rate. On the other hand, however, as has been shewn, the job rates for the sharing systems, because of the sharing principle, must be larger than with the non-sharing systems, and it is due to this factor that extended opportunities are afforded

Diagram Shewing
Job Rates Required for Different Systems.
Estimated Rate of Earnings = Time and a Third.

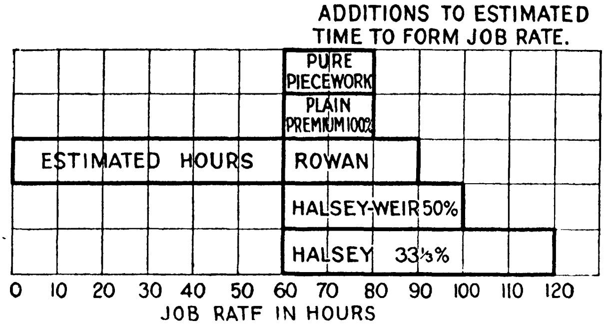


FIG. 10.

In this diagram are brought together, for purposes of comparison, the job rates required under the systems of payment by results in common use to enable earnings of time and a third to be made. In the choosing of a system of payment by results to-day, the size of the job rates required under the different systems and their consequent influence in actual cost should be considered. Actual costs can exceed the estimated cost, before the guaranteed time rate begins to operate, as is shewn in the appended table. It is claimed by advocates of the Halsey-Weir system that this system is cheaper on low outputs than is the Rowan system. It will be noted that under existing conditions this " advantage " almost disappears at some points and is more than counterbalanced at others.

COST POSSIBLE UNDER VARIOUS SYSTEMS OF PAYMENT BY RESULTS.

BASED ON JOB RATES AS SHEWN IN DIAGRAM.

ESTIMATED COST 80/-

SYSTEM.	PIECE-WORK.	PLAIN PREMIUM.	ROWAN.	HALSEY-WEIR 50%.	HALSEY 33⅓ %
Job Rate, Hours or Shillings.	80	80	90	100	120
Hours Taken.	Cost.				
60	80/-	**80/-**	**80/-**	**80/-**	**80/-**
70	80/-	**80/-**	**85/6½**	**85/-**	**86/8**
80	80/-	80/-	**88/10½**	**90/-**	**93/4**
90	80/-	90/-	90/-	**95/-**	**100/-**
100	80/-	100/-	100/-	100/-	**106/8**
110	80/-	110/-	110/-	110/-	**113/4**
120	80/-	120/-	120/-	120/-	120/-

Figures in light type indicate cost under the operation of guaranteed time rate.

slow workers for earning extra pay, by the latter being procurable for lower outputs than is the case with the non-sharing systems. This might be described as a factor of encouragement. Thus, while on the pure piece-work or plain premium system opportunities for earning extra pay cease, when 80 hours have been spent, on the Halsey $33\frac{1}{3}$ per cent. sharing system, a worker can receive extra pay when he is taking any time up to 120 hours to do the same job; that is when, say, 110 hours are taken to do a job which it is estimated should be done in 60 hours, an excess of 83.3 per cent., or when the estimated cost has been exceeded by 37.5 per cent., extra pay of 3 hours 20 minutes or 3 shillings and 4 pence will be deemed to have been earned.

Reference to the table on page 98 and to the diagrams on pages 92 and 95 will illustrate this.

In the diagram Fig. No. 10 on page 98 is shewn the value of the appropriate job rates for the different systems described, and for the hypothetical case taken of a job which it is estimated should be done in 60 hours. The difference in opportunities for slow workers under the various systems will be apparent, together with their counteracting effect on the supposed advantage of the high safety factor, what is saved with quick workers being risked with those who are slower. This is shewn in the table underneath the diagram, from which can be seen how both time wages and extra pay become payable after the estimated cost of the job has been exceeded.

Consideration of these different systems falls chiefly under three heads.

1. Nature of manufacture.
2. The appeal to the worker.
3. The effect on labour costs.

Nature of Manufacture. Conditions of manufacture present an ever-varying problem. The product manufactured in one works may be one for which, as designed, there is a constant demand, one sufficient to keep the whole plant occupied. In such a works the conditions of manufacture, within the limits of the plant and organization, should be ideal; operations can be largely if not entirely repetitive in character, and the accompanying special skill, brought about by that repetition, can be such that contingencies—uncertainties of performance, tools or workers—will be reduced to a minimum. The question of output becomes one of efficiency of training and, granted suitability of workers, willingness to produce, on the one hand, and of efficient organization and control, and supply of material and tools on the other, the possibilities of output can be known within reasonably close limits, not only to the manufacturer but also to the worker, a matter of some importance.

The need for cost safety factors will become very much minimized, and the appeal to the worker in the shape of an encouragement factor appears to be the paramount consideration. In this instance, the plain premium system could be used without risk.

In other works there may be a continual demand for the various

productions, but of less volume, so that more than one class of article would be manufactured and while operations would be repeated, the repetition may not always or at all be uninterrupted, and the conditions would be less favourable for the obtainment of the greatest volume of output. The workers, not being continually or generally on the same operations, would be unable to bring their contingency requirements to the irreducible minimum, and, consequently, the job rates would need to be somewhat more liberal, or by using one of the sharing premium systems, embody, by means of the appropriate higher job rate, a greater factor of encouragement, and, consequently, of safety. In such cases, however, neither factor needs to be of great magnitude, and it may be that, where operations are more or less mechanical, the skill required being reduced to a minimum, as, say, with certain power press, milling and capstan operations, the principle of continuity of performance is practically secured although on different pieces, and the plain premium system should give satisfactory results; of the sharing premium systems, the Halsey-Weir is the best to use in such a case.

There are productions where repetition of operations is almost nil; where every job is different, presenting problems which require varying treatment. Such cases, and they are by no means isolated —as, for example, in marine engineering establishments—embody the greatest difficulties, that have to be met in connection with systems of payment by results. Bearing in mind that the object of the system which may be in use or be under consideration, is to encourage the worker to give of his best, the question is not merely one of arriving at a correct job rate, but of the worker concerned, seeing in such job rate an opportunity of earning extra wages. He has, probably a less accurate idea of the amount of work involved than has the estimator who has calculated the job rate. In these circumstances, more particularly where the basis of the estimate is not one of proved data, one of the sharing systems will be found to be the most satisfactory to use.

The Appeal. This calls for an examination of the appeals made by the various systems, and one of the first objections raised to the sharing systems is the sharing principle itself. In this connection there is no doubt that the principles underlying these systems are not understood by the workers. The question is quite often asked why the value of the whole of the saving made is not paid to the workers; why should the manufacturer take any portion? Superficially, or if production were entirely scientific in character, and all the factors under absolute control—individual skill and energy standardized, in fact, the human factor eliminated—the answer would be in the negative; but, unfortunately, none of these conditions exist and compromises have had to be made, with the object of meeting as well as is possible a maximum of conditions which are unavoidably variable.

It is not always appreciated, perhaps, just how much individual

ability to produce can vary. The author remembers an instance where bench work was in question, the whole of the men on the benches concerned being accustomed to the work in progress. A batch of work was urgently needed, and was split up between two men. The Halsey-Weir system was in use, and the estimated time for the job was 2 hours 40 minutes per piece, the job rate being 4 hours. One man, a taciturn individual who made but few friends, had completed his pieces in 1 hour 50 minutes each, and the foreman considered there was room for doubt as to the work having been done in the time booked. The matter was being enquired into, when another man made the request for "more time to be allowed, the job rate was far too low." Strange to say the operation concerned was the same, but there was really no doubt about either performance: one man produced his pieces in 1 hour 50 minutes each; his fellow-worker on another bench had taken 4 hours—a difference of 118 per cent. between the respective outputs.

Actually, if there be any substance in the claim that the efficient worker desires to help the less efficient man, the sharing systems ought to be popular because of the extended opportunities for earning extra pay afforded under them. The return under all systems is synchronized when the average or estimated rate of output is obtained and, it is probable, that the big majority of variations in output will fall between a third above and below estimate; that is, where 60 hours are estimated as the time required for a man of average ability, the majority of the pieces will be likely to be done in and around that time, while, where that is not the experience, the variations for the most part will be within 40 to 80 hours taken. The extra pay under the various systems will be as follows:

System.	Pure Piece-work.	Plain Premium.	Rowan.	Halsey-Weir 50 %	Halsey $33\frac{1}{3}$ %
Job Rates.	80 hours.	80 hours.	90 hours.	100 hours.	120 hours.
Hours Taken.	Extra Pay Hours.				
40	40	40	22.2	30	26.6
50	30	30	22.2	25	23.3
60	20	20	20.0	20	20.0
70	10	10	15.5	15	16.6
80	—	—	8.8	10	13.3
90	—	—	—	5	10.0
100	—	—	—	—	6.6
110	—	—	—	—	3.3
120	—	—	—	—	—

Thus, when under the pure piece-work and plain premium systems, extra pay ceases when 80 hours are taken, it will still be paid under each of the three sharing systems. The encouragement offered to the less skilful worker under the sharing systems is obvious,

but it is doubtful if this factor has the slightest influence with the man whom the reducing factor usually hits—the quick man; if it had, this would augur more hope for collective systems. The encouragement factor appeals principally to the slow men, and its complement, the safety factor, is not popular with those who are more efficient; and accordingly as the operation of the latter is drastic, so will it be objected to, and the system concerned fail to induce the best results.

An example of this is to be seen with the Rowan system where, under the existing conditions, the safety factor for large outputs is of the most drastic kind. Reference to the diagram on page 106 will indicate this, while that on page 108 shews the relation of output and extra pay under the various systems. Thus, from the standpoint that the reaching of estimated output carries with it extra pay of $33\frac{1}{3}$ per cent.—it would be necessary under the Rowan system to make that output ten times as much in order to increase the earnings by 45 per cent.

The operation of this drastic safety factor can be traced in the results obtained. The general experience with the use of the Rowan system is that it is effective until the savings on job rates are equal to 50 per cent. of same, but that, after that stage has been reached, the efforts required to increase output further fall away.

In this connection the contention, by advocates of the Rowan system, that more than 50 per cent. savings are unlikely to be made, goes to confirm the weakness of the appeal of the system rather than the possibilities of output; that is their experience, and, excepting it could be proved that the difference in ability to produce between one man and another was usually within, say, 25 per cent.—and that rate-fixing errors were so small as to be negligible—then the question as to whether the influence of the Rowan premium system at the stage when more than one-half the job rate had been saved is not to restrict output, is one deserving close investigation and consideration.

Influence on Labour Cost. There can be no question at all, either theoretically or actually, that by the operation of systems of payment by results, costs of production are lower than under the time system; at the same time, the operation of the pure piece-work system and, in a lesser degree, of the plain premium system, whether job rates be given in terms of time or money, is to stabilize labour costs at a fixed level, the same being affected only by changes of wage rates and improvements in methods. With the sharing systems, while job rates are fixed, the wages cost per piece is a rising or a falling one, accordingly as the time taken is more or less than the estimated time; the cost under all premium systems rising when or before the job rate has been exceeded.

The influence on cost of production of the application of any unsatisfactory factor in a system of payment by results is one not often comparable by actual results; but in broad principle it can be
ken that the effect of the operation of a too drastic safety fact

is equivalent in its effects to the arbitrary cutting of job rates, output suffering and, consequently, costs of production. The author has had the opportunity of seeing in several large works the operation of various systems of payment by results; amongst other experiences he has seen the Rowan system displaced by the Halsey-Weir system, and has noted that, in some cases, the extra pay earned under the latter system and with similar job rates, has been increased by as much as $33\frac{1}{3}$ per cent. While in cases such as this there may be but little decrease in labour cost, the influence on oncosts is appreciable. On the assumption that a job estimated to take 6 hours can be done by quick men in 3 hours, but that under the Rowan system efforts are relaxed when 50 per cent. of the job rate has been saved, while under the plain premium and Halsey-Weir systems this would not be the case, and that, further, the time wages and oncost rates are one shilling per hour, the results under the appropriate job rates would be approximately as shewn below:

System.	Job Rate.	Hours Taken.	Time Wages.	Extra Pay.	Oncosts.	Total Cost.
Plain Premium	8/-	3	3/-	5/-	3/-	11/-
Rowan - -	9 hrs.	$4\frac{1}{2}$	4/6	2/3	4/6	11/3
Halsey-Weir -	10 hrs.	3	3/-	3/6	3/-	9/6

Viewed in a broad sense the Rowan system has comparatively little to recommend it for current use. The conditions have been changed so much that, as with the Halsey $33\frac{1}{3}$ per cent. system, its one time "good" feature has become its worst. Inducement all the time, without unduly high job rates, is necessary; at the same time the conditions obtaining to-day are such that all systems are affected in some way, in no case to their greater efficiency. Further, it cannot be said that under any system in use, excepting the pure piece-work system, is there any logical connection between earnings or extra pay and output, although this applies to collective as well as to individual systems, and justifies a chapter to itself.

CHAPTER VIII

THE RELATION OF EARNINGS TO OUTPUT

It has been stated that the conditions which the various systems of payment by results have been devised to meet have been changed, and it has been demonstrated that the changes made have affected their efficiency. All the systems are affected, and the position obtaining to-day is that, with one exception, the piece-work system, the payment made under each of the systems in common use is based on considerations which are purely arbitrary, and which have no logical connection with output. This is no reflection on the devisors of the systems. When the latter were devised there was no call for anything beyond factors which would ensure reduced labour costs; the basis of all calculations was that of past performance, and the method of dividing the time saved was bound to be of an arbitrary character.

The position to-day, however, is quite different, and while there is yet much work to be done, the aim in every direction is to work on definite bases. The workers desire to earn " time and a third " ; the employers seek output at not less than a definite rate, but what the relation of earnings to output should be does not appear to have been given attention. Quite apart from the manner in which the various systems are affected by the changes made as regards the appropriate job rates, it is worth while considering what the relation of the money paid for work done is and should be.

The systems in common use have been discussed from the standpoint of their application and appeal. It is well known that many workers have a distinct objection to the sharing systems, because they think the whole of the savings made should be paid to them. The arguments with which these objections are met are invariably weak, because, now, there are no logical reasons to be put forward in support of same. Sometimes ineffective statements are made that the firm has spent money to improve tools, methods, etc., and that, consequently, some return for this is required ; but instead of taking all the savings made possible by these improvements, the firm is willing to share them with their workers. Such statements, although superficially logical, are unconvincing, and really they are all moonshine. Improvements in methods and tools justify the

modification of job rates, and the majority of firms act accordingly; if they do not they are foolish, although, even where they do not, the argument referred to above is not founded thereon. What is happening is that the old arguments are being used for conditions to which they do not apply.

The only reasonable arguments that can be put forward in this connection are two: one that the job rates under the sharing systems are larger than those appropriate to the plain premium and piece-work systems, and that it is but fair, seeing a portion of the savings made are due to this extension of job rate, that the employer should receive a share. This argument does not go far, however, and fails at once when the question is asked as to why the extra addition, so made, is made, and what are the objections to the use of a non-sharing system. The second is, though not often used, that by guaranteeing the payment of time wages the worker is protected against the unfairness of low job rates, and that in this being done the employer is subjected to loss when incompetent or indolent workers fail to reach the output estimated.

To be candid and honest, the only reason which operates is the doubt as to whether the job rates are correct or not, and that, if too high, the reducing factor of the sharing systems will prove to be a corrective. If these correctives are considered from the point of view of the return made under the different systems in common use, the variation is such as to appear to be quite outside the bounds of necessity.

In the diagram given on page 106 is indicated the relation of output to earnings under the systems in common use, from which it will be seen that for four times the estimated rate of output, the return to the workman in the shape of gross earnings varies from 37½ per cent. extra under the Rowan system to 300 per cent. under the Plain Premium system, and the same systems are to be found in use on precisely the same classes of work. There is really no logical defence for this variation, nor does there appear to be any reason why attempts should be made to maintain a position so weak and untenable; an examination of the facts will indicate that it is possible for the present conditions to be met by the use of one of two systems by which output, earnings, extra pay, risks and safeguards, will be brought together in a logical, straightforward and extremely simple manner.

The weakness of the piece-work system has been discussed, but it is the only system in common use under which the relation of output to earnings is truly logical. Under that system a stated amount of money is offered or agreed upon for the carrying out of a specified operation. Once a job rate is accepted the relation of earnings to output is definitely fixed. Time worked ceases to count; earnings are increased or decreased in the exact proportion by which output is given. The contract is a definite one and has a logical basis: double the work, double the pay; half the work, half the pay.

With the guarantee of time wages, however, the position is not

quite the same. Up to a point wages are paid without respect to output ; extra pay begins only when a certain task has been accomplished and, theoretically, the extra payment made is not for the whole output, but for that proportion of the output given above a stated minimum.

Diagram Shewing
Relation of Increased Output to Earnings
Under the Following Systems :
Plain Premium 100 %—Halsey-Weir 50 %—Halsey 33⅓ %
Rowan—Taylor.[1]

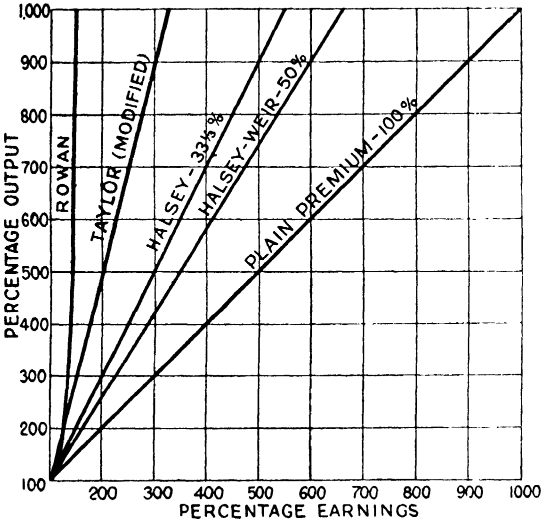


FIG. 11.

The basis of the diagram is that for reaching estimated output the normal earnings will be equal to " time and a third." Estimated output with the appropriate rate of earnings are each given a value of 100. Under the different systems the respective earnings for various rates of output are as shewn.

RELATION OF OUTPUT TO EARNINGS

System.	Output. 200 %	Output. 400 %	Output. 800 %
	Earnings.		
Rowan	125 %	137.5 %	143.75 %
Taylor	125 %	175 %	275 %
Halsey 33⅓ %	150 %	250 %	450 %
Halsey-Weir 50 %	162.5 %	287.5 %	537.5 %
Plain Premium 100 %	200 %	400 %	800 %

[1] For description see page 111.

For example, if for the 60 hours estimated time used in the various diagrams in Chapter VII. to illustrate the different individual systems, 60 articles are expected, requiring, say, with the Plain Premium system a job rate of 80 hours, then any extra pay earned will not be because 60 articles have been made, but because they have been made in less time than 80 hours. If 45 articles only have been made in 60 hours instead of, say, 60 articles, no extra pay will have been earned; while if 36 articles only have been produced, then, although their wages value will be but 48/-, the wages cost will be 60/-. In the latter case, under the Halsey system, extra pay of 4 hours would still be due bringing the cost up to 64/.

The position to-day is vastly different to that of yesterday. To guarantee time wages when the job rates could not serve to increase costs, as was the case when time taken was used as a basis, and to guarantee to do the same when it is necessary to provide opportunity for earning 33⅓ per cent. extra pay are propositions having a very great difference. Not only so but, as has been shewn, the application of the sharing principle, with the correspondingly higher job rates required, carries with it a provision by which estimated costs can be exceeded as output falls below the amount estimated. Whatever may have been the advantages of the old systems their suitability for use to-day cannot be taken for granted and, with job rates based on known possibilities of production, as against time taken, some logical connection between output and payment would appear to be possible.

There appear to be but two distinct principles upon which payment can now be logically based :—

1. Earnings to be entirely dependent upon and to be proportional to output.

2. Time wages to be guaranteed independently of the amount of output, extra pay to be dependent upon and to be proportional to the amount by which output is increased above a fixed minimum.

If these principles be the only two which can be logically applied, then, automatically, the nature of the systems by which they can be given effect to are decided, and neither of the premium systems in use meets the conditions.

Dealing with the second principle first, the basis is really a task, the accomplishment of which carries with it a certain addition to time wages. If 60 articles be produced in 60 hours, this addition to wages will be equal to 33⅓ per cent. of same. It is not illogical to argue, and it is quite in keeping with the principle of paying a premium, that if the output be doubled, the extra pay shall be doubled also, and so on, the *amount of time wages paid not to be affected by either an increase or a reduction in output.*

What are the objections to such a course? Logically there seems to be none. With the piece-work system there is no guarantee that time wages shall be earned or paid; the basis is work done; there are industries where time rates are not given at all. The risk of

Diagram Shewing
Relation of Increased Output to Extra Pay
Under the Following Systems:
Plain Premium 100 %—Halsey-Weir 50 %—Halsey 33⅓ %—Rowan—Taylor.

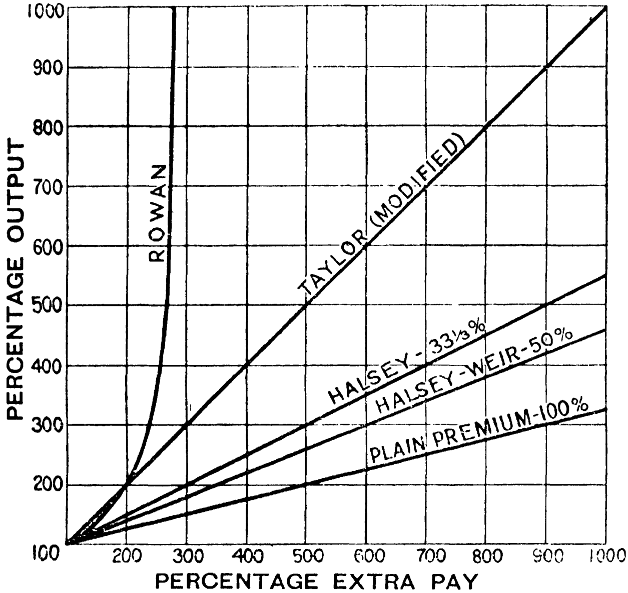


FIG. 12.

The basis of the diagram is that for reaching estimated output extra pay of 33⅓ per cent. is made. In each case the achievement of 100 per cent. of the output estimated carries with it 100 per cent. of the extra pay arranged for; for other outputs the extra pay due is quoted as a percentage of the amount provided for when estimated output is reached. The following figures give the percentage of the extra pay due under the various systems for the output shewn.

RELATION OF OUTPUT TO EXTRA PAY

System.	Output. 200 %	Output. 400 %	Output. 800 %
	Extra Pay.		
Rowan - - - - - -	2	2.5	2.75
Taylor - - - - - -	2	4.0	8
Halsey 33⅓ % - - - - -	3	7.0	15
Halsey-Weir 50 % - - -	3.5	8.5	18.5
Plain Premium 100 % - -	5	13.0	29.0

The wide differences between the amounts of extra pay made under the various systems will be obvious, and on the assumption that the basis of job rates is now one of knowledge of possibilities, are somewhat difficult to reconcile.

too high a job rate is then the employer's, but he has the assurance that his work will not cost more. The worker's risk is that of accepting too low a job rate, but he in turn has the satisfaction that he will be entitled to all he earns.

The difference under the guaranteed time rate is that the worker's risk is entirely eliminated, while that of the employer is increased. Should there not be a counter-balancing provision which would compensate the employer for the risk taken, and if so, is not the most logical method to keep time wages entirely apart from output considerations and to reward increased output by increased extra pay? Superficially, the answer is bound to be in the affirmative. Some firms endeavour to recoup themselves for the losses which follow the operation of the guaranteed time rate by using what is known as the "debt" system. Under this system any loss which may be made on one job must be made up on subsequent jobs before any extra pay is made. That is to say, if a worker's time wages exceed the job rate on one job by 5/- and he has earned extra pay on another job of, say, 10/-, 5/- of that 10/- will be deducted to make good the loss on the first job. Where the reason for the loss is attributable to the worker and not to the insufficiency of the job rate there is really nothing unfair in this, but the system is not an easy one to work, particularly on small work; it is open to grave abuses, and in many instances the results are entirely unsatisfactory.

From the standpoint of practice, however, there can be no serious objections to an increase in output being remunerated by a proportional increase in extra pay, because to do so is to strike a line which is midway between the extra pay possible under the systems now in use—the Halsey-Weir and the Rowan systems. The diagram on page 108 illustrates this. From this it will be seen that for four times the output the extra pay under the Rowan system is 2½ times the amount secured by doing the work in the estimated time, while under the Halsey-Weir system for the same amount of work 8½ times the extra pay is given. It would appear to be more logical if the amount of extra pay were 4 times as much for 4 times the output.

In that diagram will be noted a line representing the "Taylor" system. This system is credited to Dr. Taylor of America, and while it would not appear to be greatly used, it has features which go to indicate that not only by its use are output and extra pay logically and proportionately connected, but that under it are avoided some of the greatest objections to which premium systems have been subjected.

Under the Taylor system a job rate is not given in the ordinary way; a fixed premium is offered and is paid so long as the operation is performed within a given time, and this worked out will be seen to give an increase in extra pay proportional to the increase in output. In the first place, figures are quoted below to indicate the extra pay required for the increased output quoted. For purposes

of illustration it will be taken that 60 articles should be done in 60 hours, and that that output should carry with it 20 hours extra pay, increased output to carry with it a similar increase in extra pay.

Number Done.	Hours Worked.	Extra Pay. Hours.	Percentage Increase.	
			Output.	Extra Pay.
60	60	20	—	—
120	60	40	100	100
180	60	60	200	200
240	60	80	300	300
300	60	100	400	400
360	60	120	500	500

Transferred into terms of the Taylor system the reading would be as follows:

Number Done.	Hours Worked.	Extra Pay		Percentage Increase.	
		Hours.	Percentage.	Output.	Extra Pay.
60	60	20	33.3	—	—
60	30	20	66.6	100	100
60	20	20	100	200	200
60	15	20	133.3	300	300
60	12	20	166.6	400	400
60	10	20	200	500	500

One weakness of the Taylor system appears to be that there is a sudden cessation of the extra payment at the point when the task has not been accomplished. If the job takes a longer time to do than 60 hours, no extra pay is due, and the consequence is a sudden drop in earnings at that point. Thus one man who took 60 hours would receive 80 hours pay, while another who took 60½ hours would receive 60½ hours pay only. This would be likely to cause discontent. Worked as shewn below, however, 33⅓ per cent. earnings being the basis, the system undoubtedly deserves attention.

The time in which it is estimated the various jobs could be done could be quoted direct to the worker, together with the appropriate amount of extra pay, thus:

Estimated time = 60 hours.
Extra pay = 20 hours.

The worker would know without calculation of any kind that, provided the estimated time was not exceeded, 20 hours extra pay would be secured, independently of the amount of time saved. In the event of the estimated time being exceeded, the operation of the formula given below would provide for a gradual fall in the hourly rate of earnings, while the estimated cost would be precluded

TAYLOR SYSTEM (MODIFIED).

Diagram Shewing

Hours Taken—Time Wages—Extra Pay—Actual Cost.

For Different Outputs against Estimated Cost.

Estimated Rate of Earnings—Time and a Third.

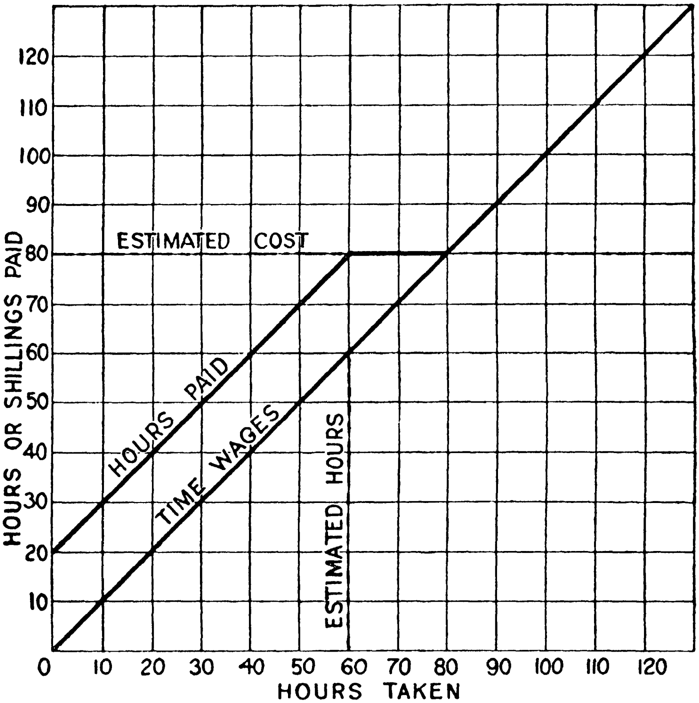


FIG. 13.

Under the Taylor System, as devised, a definite task was set, for the performance of which a fixed amount of extra pay was offered. Thus if 60 hours were the estimated time, and 20 hours were fixed as the extra pay amount the time wages value of 20 hours would be paid as long as the time taken was not greater than 60 hours. The extra pay made was in direct proportion to the increased output given, and this provision makes it the only logical premium system in existence to-day in so far as earnings and output are concerned. If modified as shewn, so that any excess of time taken above the time estimated is deducted from the extra pay amount, there will be no sudden drop in earnings at that stage, nor any increase in cost due to extra pay, as is the case with the Rowan system and those in the Halsey group.

Under this system the principle of sharing the savings made, to which much objection is expressed by workers, can be obviated, and by so doing a system is possible which appears to be the simplest, the most easily worked and most logical of all the premium systems and one to which the least objection could be offered by the workers.

from rising except through the operation of the guaranteed time pay.

$$\text{Extra pay} = \frac{\text{estimated time}}{3} - (\text{time taken} - \text{estimated time}).$$

Then in the case of an operation with an estimated time of 60 hours, and 50, 60, and 70 hours are taken respectively, the extra pay would be worked out as follows :—

$$\text{Extra pay} = \tfrac{60}{3} = 20 \text{ hours.}$$

Extra pay when 50 hours are taken	= 20 hours.
,, ,, ,, 60 ,, ,, ,,	= 20 hours.
,, ,, ,, 70 ,, ,, ,,	= 20 – (70 – 60)
	= 20 – 10 = 10 hours.

As well as being provided with a logical basis, there is an advantage from another standpoint with the Taylor system as modified. The sharing systems always have been, and perhaps always will be, objected to because of the sharing principle, and the more drastic the reducing factor, the greater the objection and the poorer the appeal such system will have, quite independently of the high job rates now called for in consequence of those same factors.

With the system under discussion, however, division of savings is not involved. A plain premium is offered, irreducible in amount so long as the estimated time is not exceeded, which, at the same time, remunerates increased output proportionately by an increase in extra pay. That system is more liberal than the Rowan system, but has less objection than the Halsey and Halsey-Weir systems with their high job rates, and in this respect might be held to offer less inducement to the cutting of job rates than may be the case with them. A point of great importance, however, is the avoidance of the contentious practice of dividing the savings made.

The diagram on page 111 shews the cost and extra pay due for the various outputs under the modified Taylor system.

One of the arguments used against premium systems is that the calculations required are such that the workers do not understand them, and get confused and suspicious as a result. Whatever such an argument may be worth as regards the rising generation—it is no compliment to our educational system—the Taylor system, up to the stage where the estimated time is not exceeded, is simpler even than the piece-work system, because neither multiplication nor subtraction is called for. When the estimated time is exceeded the calculation becomes one of plain subtraction, although the worker will probably add the estimated time and the extra pay amount and deduct the time taken ; this is simpler even than piece-work calculations.

From the standpoint of working costs, the Taylor system is worthy of attention. As has been shewn, the calculations required are less than under the piece-work system, and this would mean real economy in clerical labour, as well as a greater absence of mistakes in working out.

In another connection an advantage is possible, namely, that in quoting the estimated time as the basis on which extra pay would be made, the significance of same would be made plainer. There is a tendency to look upon any performance as satisfactory which is not in excess of the job rate, and in many works enquiries are sought in connection with those jobs only on which the job rates are exceeded. Notice of this kind would not be called for under the various systems until the position was as follows:

System.	Time.		Job rate not Exceeded till Estimated Value passed by.
	Estimated Value of Job.	Job rate.	
Plain Premium, 100 %	133.3	133.3	Nil
Rowan - - -	133.3	150.0	14.2
Halsey-Weir, 50 % -	133.3	166.6	25.0
Halsey, 33⅓ - -	133.3	200.0	50.0
Taylor (modified) -	133.3	133.3	Nil

The weakness of not making enquiries until the job rates have been so exceeded will be obvious, but this is the practice followed in some large works to the detriment of the companies who own them.

From all standpoints it is desirable that this question should be put on a logical footing, and if this principle of payment could be agreed upon, a system capable of universal application would be available which, as well as being simple to follow, would secure all the advantages which the sharing systems can give in the shape of the avoidance of the need to cut job rates, would preserve the principle of the guaranteed time rate of wages, and would ensure an increase of extra pay strictly in accordance with increased output.

From the employer's point of view, the objections of the sharing systems would be avoided where the continuance of extra pay was concerned after the estimated wages cost had been exceeded; while, on the other hand, he would know that the payments being made were on a basis which was logical, and would enable him to avoid the sophistical arguments which under the sharing systems with an estimated basis of job rates were his chief defence.

CHAPTER IX

PROFIT-SHARING IS NOT PAYMENT BY RESULTS

In some quarters it is thought that a scheme of profit-sharing would provide the solution to much of the trouble surrounding the employment and remuneration of labour, the idea being that by giving the workers a pecuniary interest in the making of profit their interests would be identified with those of the employer and that as a consequence their aims would be unified. Further to this some people claim that profit-sharing is a substitute for and an improvement upon payment by results.

Under certain circumstances both these views may be correct, and there is no doubt that the first mentioned has much to recommend it; the latter, however, would appear to have but limited application, and in some industries, as in engineering, no logical application at all.

Under an equitable scheme of profit-sharing there can be no doubt that the interests of all parties would be directed toward the successful running of the works, but the making of profit depends upon many factors other than that of individual output, and these can render profit-sharing quite an ineffective means of inducing a high rate of output and therefore unsuitable for the remuneration of labour.

It has been shewn that payment has been made in accordance with results as a means of inducing the worker to carry out the tasks assigned to him in as efficient and expeditious a manner as his ability and the facilities provided will allow. This is a clearly-cut and definite object, which neither theoretically nor actually has any real complications. The worker reaps the benefit on a definitely agreed scale of the successful result of his efforts. Under profit-sharing this is not the case, nor does it follow that a profit is ensured even when the rate of output obtained is the best possible.

Profit—the term needs no explanation—will depend upon many things; manufacturing policy; the utility of the product; the state of trade; wise buying; effective selling arrangements; the suitability of the plant; the efficiency of the organization and of supervision; efficient labour and the efficient use of labour. Each

of these can affect profits, and some of them are more effective in their influence than the energies of the workers themselves. One of these only, however, is subject to the workers' direct influence, their own energies and abilities.

Logically, payment can be made in accordance with the results only when the conditions which affect them are under the control of the people to whom the payment is to be made. To expect the efficient efforts of the workers when these can be more than counterbalanced by so many different and influential considerations is to be optimistic rather than practical, and in such circumstances profit-sharing must carry an appeal of even less value than that of collective systems of payment by results to which profit-sharing is allied. In collective systems, the remuneration is rarely made to depend upon anything other than output, and although this can be affected by organization, supervision and the methods employed, it cuts out many of the factors which operate with profit-sharing.

As an illustration, an example may be cited where, owing to a faulty manufacturing policy, orders for many new products were placed ; technical staffs were increased, special tools, jigs and fixings were made, but before any articles were completed manufacture was dropped. In other directions stocks of raw materials and of finished goods were accumulated, for the latter of which years have been and will yet be required to find purchasers, meaning lean times for long periods.

It is at such times as these that the best efforts of the workers are most to be desired in order to counterbalance the bad effects of such a mistaken policy, but under a profit-sharing scheme used as an alternative to payment by results, the inducement would be absent when most required, and the workers' earnings would be affected because the directors of the concern employing them had pursued a wrong policy.

From another point of view profit-sharing is likely to fail to induce the best results so far as efficient effort is concerned, and that is the collective nature of the return made. The results of individual effort being merged into one large whole lose not only their identity but also their comparative value, and it soon becomes apparent that the net results of one man's efforts upon the total are comparatively small, and, consequently, there is a decided tendency to slacken the efforts put forth, particularly when indolence or inefficiency is apparent elsewhere.

In another connection, profit-sharing in the engineering industry is not calculated to achieve the best measure of success as an alternative to payment by results and that is the fluctuation of employment together with the uncertain possibility of receiving a profit at intervals of 12 months. The appeal fails to grip right from its inception, and on the understanding that a share in the profits made is offered because of the need for a greater volume of output, the failure of the appeal must mean failure to improve the output position either at all or as much as is possible.

It could be argued that payment could be made to account at periods more frequent than every 12 months, an estimate of the position being made periodically. There is no doubt that this could be done, and where the products manufactured were small, so that monthly statements of the position could be produced with approximate accuracy, there would not be any serious objection to such a course; but where large units and a varied programme were concerned, a real element of danger would be present, and, if payment of profit were made to account on the basis of a faulty estimate of the position, the repayment of same would be a delicate matter.

There is little doubt that the sharing of profits would induce a desire in workmen to remain with a successful firm, and provided arrangements were made to pay workmen whose services had been dispensed with, with the proportion of the profit due to them, such a scheme could have beneficial results.

It would be possible, of course, and it would also be a good policy, to make payment by results and to share profits as well. It may be thought that this would be to give a double reward, but this is not so. The policy would be a recognition of two separate and independent factors. In the one case, under payment by results, payment would be made for the efforts put forth according to the individual efficiency achieved under the conditions ruling. In the other, the existence of a profit would indicate a measure of prosperity and the sharing of same would be a recognition of the success which was the result, in part at any rate, of the united efforts of all.

Such a policy, as well as unifying the interests of all concerned, could be used further to intensify the desire of the individual to earn high wages by sharing the profits in accordance with total earnings. Thus if three men whose time wages were alike but whose individual earnings, because of their varying abilities, were, say, £130, £160 and £190 per annum respectively, the proportion of profit due to each would be in accordance therewith. This, of course, would react on output and thereby would tend to discourage any form of restriction. The weakness of the appeal, when long intervals took place between payment of profit would not be overcome, although it would be lessened to some extent.

It will be obvious that the relation between output and profit can be so much affected by other factors and, therefore, be so distant as to render almost valueless, so far as the attainment of efficiency is concerned, the apparent connection between the two.

CHAPTER X

JOB RATES AND THEIR RELATION TO OUTPUT

BEFORE any useful discussion can take place as to what job rates should signify, it is necessary to define the term. Nominally, the term job rate is used to designate the amount of time or money fixed as the rate of remuneration to be paid for the successful carrying out of a given piece of work. Many different terms are found in use, however, all having reference to the same things, among these being piece-work price; piece-work rate; price; standard time and basis time; time limit; standard time allowance; standard cutting time; bonus time. The use of the first three is usually confined to the piece-work and plain premium systems, the rates being expressed in terms of money, although there are cases where piece-work job rates are expressed in terms of time, the same descriptive terms being used as with the premium systems generally to which the remaining terms are usually confined.

The term job rate is used in this book to cover the rates given under any one of these systems, and because of its universal application helps to avoid confusion. There is really no need for the terms used to be varied for the different systems, although the matter is not of great importance.

In some works, not only are different terms used in referring to that which is here known as job rates, but such rates are given different values, their bases being of a widely divergent character. Two schools of thought and, one might almost say, two eras are represented by the policies controlling the manner in which the respective rates are arrived at, and in so far as on the one lies much of the responsibility for the troubles surrounding payment by results, it will be advantageous to consider the uses and the significance of job rates fixed under the two methods.

In the early days of payment by results, job rates were not only based on time taken, but the time recorded as taken was used as the actual job rate, either in its existing form as time, or when converted into terms of money at the appropriate time rate, and at that stage of the evolution of production engineering the practice followed was the best which had been thought of. The various

systems of payment by results were designed to meet this condition, and it is due in part to the success which has attended their use that, in engineering output, such strides forward have been made.

What cannot be so readily understood is the contention that is still held in some quarters and the policy still followed, apparently, in some works, that job rates should be based on average time taken or on the time observed to be taken. The latter is the most important, although to put the two forward as alternatives appears to be most incongruous. Literally it means, if a job were done under observation and the time taken were 10 hours, that 10 hours would be given as the job rate and that any extra pay earned would be dependent upon the time taken being reduced below that which had been observed. This would render the making of extra pay a matter almost of impossibility, or the inference is that the nature of the observation must be so mechanical and devoid of value as not to be worth the making.

Really it is a colossal error to imagine that there is necessarily any relation between the time recorded as taken under the time system and that recorded as the result of an intelligent and efficient observation. If it were so, then the value of payment by results in such cases must be practically nil, and the possibility of earning extra pay would be little more than a fantasy. Where ordinary recorded time is concerned, this method, in so far as it would not serve to increase cost, is not unsound; but under observation, theoretically, the rate of output obtained should be such that to surpass this would be almost impossible, while to fix job rates on a basis, under which are offered such slight chances of reward, is really the negation of all that payment by results stands for.

At the same time, a sound principle underlies this much mistaken policy, and that is, that job rates should never be so high that costs could be increased through their agency. It will be remembered that reduction of costs was the object of all the systems of payment by results in use in this country, and the reason for the different views held to-day is that there is a wider difference between the rate of output given and that possible than was, at that time, thought to be the case. Thus, if the time taken on a given operation were 10 hours, but, by a process of estimating or observation, it became apparent that the work could be done in 5 hours, the job rate to be fixed should not be 10 hours, but say, under the Rowan system, 7½ hours. If the job had been efficiently observed and had been done in 5 hours, then surely there would be great inconsistency of job rates if 5 hours only were given and, in the absence of observation, 10 hours were given in another but similar case.

What really is in evidence, where a policy of this kind is recommended, is the old narrowness of mind which has ever characterized wage paying. It is one almost entirely of negation. If costs are high, less wages must be paid; if payment by results be introduced, care must be taken that job rates are not higher than the existing time taken or cost. Not unsound so far as it goes, but it is too

timorous. There is no virtue in making sure that a job rate of 10 hours is not in excess of the time originally taken, if the job can be done in 5 hours, while it is an utter absurdity to fix a job rate of 5 hours for a job which cannot, in the ordinary way, be done in less time. There is a big difference between the two propositions, and they really register a parting of the ways between the old policy of improvement and that which makes control possible, and makes for efficiency as well.

Bearing in mind that the object underlying the use of payment by results is the inducement of the best efforts, it is obvious that job rates must indicate a time greater than the minimum time in which the different jobs can be done, and it follows that such rates, if based on the value of the work rather than on records, must be in excess of the time which has been estimated or has been satisfactorily observed as being possible. The job rate itself cannot stand for rate of output and present opportunities for earning at the same time, a fact which has caused some people to stumble. It has been recommended and, it would seem, practised in some works that when job rates are based on estimated time the aim should be to estimate the job rate itself and not the time in which the job ought to be done, the job rate to represent the time a man of average ability would take when working on the time system.

This is an example of the exceedingly loose thinking which has accompanied the use of payment by results. The three methods are contradictory to general experience and to all logic. Average time taken reflects ability and, most likely, some inefficiency. Observation worth the name, in the majority of cases, should ensure results which it would be almost impossible to beat; to estimate the job rate itself must mean either to estimate on an entirely false basis, or to arrive at job rates which would effectually neutralize the influence of payment by results.

It is difficult to understand what is really meant by estimating on a time basis. Experience teaches that there is a difference between the rate of output obtained under different systems of payment, and it would appear that an estimate for a rate of output appropriate to the time system would be one where the speeds or feeds allowed were slower than would or ought to be used, or that more cuts would be allowed than required. This can hardly be meant; and yet what opportunities would be presented for earning extra pay if the true machining time were accurately estimated and used for the direct job rate? For purposes of illustration consider a planing machine on which are used known feeds and depths of cut; if the cutting time be correctly estimated and given as a job rate, what possible opportunity can there be for a reduction in the time so taken?

There is but one solution, and that is to estimate the time in which jobs ought to be done and to add the amount necessary under the different systems to enable extra pay to be earned. This forms the one plain and significant factor which cannot be ignored, mini-

mized or exaggerated; not only so, but by it most valuable information can be presented for use in other directions. There is nothing wrong, however, although there is an element of risk under present-day conditions, in making such an addition; at the same time, the position, with the risk, is more satisfactory than it would be without it.

It is more common to-day than was formerly the case to link up the job rates fixed with estimates for tendering purposes. From one point of view, that of avoidance of loss, this is sound, independently of the bases used in fixing the rates; but job rates are now being used in an increasing degree as the basis of the works production programmes. To this end, of course, something more reliable is required than the uncertainties of what men choose or are able to give in the shape of output. The difficulty of obtaining contracts, of meeting delivery dates, and of keeping financial commitments down on as low a basis as possible makes it necessary for some reliable knowledge to be available as to the time by which the different items will be required; the amount of time the various operations will take; the capacity of the plant in the various types of machines, and estimated time—not job rates—must be the basis of this knowledge; this is now being used in many works not only in making up the various production programmes, but also in the building up of machine programmes for new workshops.

As stated earlier, the situation has undergone a further change, the importance of which cannot be overlooked, and which makes it more than ever necessary to estimate carefully the time in which operations ought to be done. In the year 1919 it was agreed by the Engineering Employers' Federation and the Engineering Trade Unions that job rates should be so based that a man of average ability would be able to earn 33⅓ per cent. extra pay. The provisions of this agreement put quite a different face upon the question, and one which raises several somewhat delicate issues. Thus, merely to ensure that work will not cost more, even if the time previously taken be used as job rates, there must be an immediate increase of output of 33⅓ per cent., and if output could not be so increased, then payment by results could be introduced only by the facing of extra labour cost or by the non-observance of this feature of the agreement. True, in most works, an increase of this amount is possible, but in a works where production has been reasonably well managed difficulties will be found if the margin of inefficiency is not sufficiently great to enable the management to comply with the arrangements made.

To meet the conditions now obtaining, job rates can no longer be the simple proposition to which some firms have clung so tenaciously. The necessity to provide opportunities for earning 33⅓ per cent. extra pay requires at once that the basis of job rates must be the possibility of performance and not previous cost. It does not appear to be worth while discussing the estimating of the job rate itself when obviously the basis must be a false one if the rate is to hold

any kind of appeal. The chief feature of the job rate will not be its total, but the basis on which that total has been constructed, and this must obviously be the time in which jobs ought to be done by men of average ability. This being arrived at, that amount must be added which is necessary under the respective systems in use to provide the opportunity for earning the amount of extra pay which it has been specified must be provided for. Under each of the three systems described in Chapter VII. the job rates will have to be different. This is indicated in the diagrams relating to the various systems, and in those shewing the difference the changed conditions make.

In those works where the average time taken has been used as a basis for job rates, this will mean a change of policy, and it is in the interests of all concerned that the change shall be made with due regard to the avoidance of increased costs. It is not going far enough, however, to ensure that costs shall not be increased; the road must be left open for efficient costs to be ensured. How is this to be achieved? On what are the job rates to be based? How are they to be arrived at? It is possible to follow a somewhat old practice and deduct 25 per cent. or some other amount from the hours taken and to call this an estimate, adding to this the amount necessary to make up the job rate; but, even if a policy of such doubtful wisdom were followed, the job rates for each of the systems, excepting piece-work and the plain premium system, would need to be higher than the time previously taken.

Under such a method, the job rates under the old and the new conditions would be as follows:

Time Taken 1 Hour.	System.		
	Plain Premium.	Rowan.	Halsey-Weir.
Job rate—Old method	1 hour	1 hour	1 hour
,, ,, New ,,	1 hour	1 hour $7\frac{1}{2}$ mins.	$1\frac{1}{4}$ hours

When the job is done in 45 minutes the extra pay in each case will be 15 minutes, the time cost, as before, being 1 hour.

The fact that a definite amount of earnings must be provided for renders it inadvisable for any basis to be used for job rates other than that of knowledge of possibilities. Failing this, the safeguarding of costs from rising under the new conditions will present many difficulties, while the defence of the job rates given in this manner would become a most precarious task. The present conditions demand that the basis of job rates shall be a tangible basis, one which will enable job rates to indicate a standard of efficiency not, as those based on time taken have been, the low water-mark of inefficiency.

CHAPTER XI

THE BASIS OF JOB RATES

IN considering what shall be the basis of job rates, one is met with many different sets of conditions and with various methods of arriving at job rates. As shewn in Chapter X., job rates should have a positive and not a negative basis; the basis should be proved possibilities rather than pious hopes. It is clear that much of the inconsistency of job rates so much in evidence in the past has been due to the fact that the basis has been one of inconsistency, one in which would be reflected the ability, energy and will of the various workers to produce, handicapped or assisted by the shop conditions and the state of the organization generally at that time. In the job rates so fixed many factors would operate, of which no record would be made or even noted. It may be the material used was unduly hard or too big; that the machine used was unsuitable; that in a fitting operation far too much material was left by the machinist for removal. In a record of time taken only, these facts are likely to be ignored.

For this weakness to be avoided it becomes necessary that job rates should be based on the work to be done, which is definite, under conditions which ought to obtain, and these can also be defined. Variations of any one of these can then be traced and allowed for as may be necessary. What are the best means by which a satisfactory basis for job rates can be arrived at; and what influence will the different classes of work have on the methods to be used?

Enquiry will disclose the fact that the methods used to-day range from time taken to calculation, there being innumerable shadings and overlapping of all these. The first essential, however, is that the basis must be the amount of actual work to be done; the second is, there must be a written record of the work allowed for, in which the conditions obtaining must be noted. So soon as this is commenced some progress is likely to be made. If the methods adopted are such as to reflect efficiency, so much the better, but an important feature is a written record. A comparison of work done rather than of time results then becomes possible, and comparison that is real is the starting-off point of progress.

It is claimed that comparison is often used in this respect where records are concerned, but a comparison of time results without adequate knowledge of the conditions is not sufficient, and in view of the fact that there is a tendency in workshops to observe a certain rate of output on the various jobs, comparison without analysis can be taken but little farther than to deal with results. It is not only that, in the fixing of job rates which present unequal opportunities for earning, discontent is caused amongst workers, but inconsistency of cost becomes unavoidable.

Thus, if two jobs be considered, "A" and "B," the average time taken for each of which was 10 hours; if, under payment by results, the time taken were used to form the job rates in each case, and these were reduced as follows, "A" to 8 hours and "B" to 5 hours, the extra pay earned under the plain premium system would be 25 per cent. on "A" and on "B" 50 per cent. If the times taken under payment by results reflected the true time values of the jobs, the cost for "B" would be 50 per cent. more than the job was actually worth, while the amount of extra pay earned, apart from being the result of unequal opportunities, would not indicate the respective abilities of the men concerned, but would reflect nothing further than the disparity of the rate of output previously obtained and now permanently embodied in the job rates.

It may be argued that records of this kind are not accepted blindly, that discrimination is used, and that those records which appear to indicate unduly low output are investigated, the job rate being modified in consequence. There is probably no doubt that this is done, but the admission at once destroys the value of the greatest argument which has been used in its favour; if the average time taken cannot be relied upon as a basis for job rates, then all records must be reviewed, otherwise the discovery of those records which reflect low output would be a matter of chance.

To fix rates by comparison is but another form of using records, the only additional factor required being that of the experience and judgment necessary to decide the time value of the difference between any two jobs. Obviously such a decision will reflect the rate of output usually obtained and recorded, and this, if honestly used, can be only negative in its influence. In some cases the opportunity is taken of fixing new job rates a little lower than those of the parts with which comparison has been made, but the policy is a blind one and not to be recommended.

Experience. In some works job rates are based on experience, and while it would be unwise to decry experience, yet it will be readily seen that experience only can be a most unsatisfactory basis. What is experience? In this connection, by experience is usually meant practical personal knowledge of the work and its possibilities as regards output, and it follows that for the knowledge to be both practical and personal it must have been obtained in that particular workshop in which an appointment is still held, and therefore must be of precisely the same character and value as the records to which

reference has already been made. Really, experience cannot be more than a mental impression of the rate of output generally obtained, and this should be more accurately recorded in a firm's books.

There is one possible advantage experience can have over the use of records, and that is when the experience of the person concerned has been obtained in a workshop where the rate of output was better than that in which the experience is to be applied. In such a case the tendency would be to lift the rate of output to, but not above the level obtaining in the shop where the experience had been obtained

Observation. The observation of the time taken is thought by many people to be the safest method of fixing rates, the argument being that proof is constituted thereby, that the job can be done in the time stated, while, at the same time, the opportunity has been presented for ensuring that no time has been wasted in the performance thereof. This is obviously true; but although the elimination of wasted time is a desirable aim, yet, in so far as by that is meant keeping the workers busy only, this will not of itself ensure efficient results. Much will depend upon the methods used and the efficiency of the observer, as well as upon the attention given.

There are a number of works where this procedure is adopted, job rates being based on the time taken on a given quantity. Sometimes the foreman is held responsible for this observation being made, but, having many other duties to attend to, he can do no more than give casual attention, and the results of such observations have proved to be most unsatisfactory. Examples Nos. 6, 7, 10, 11 and 12, in Chapter II. are illustrations of this.

This is no more than can be expected, for after all the worker is not likely to have any higher standard of morality than his employer, and he obtains the best terms possible whether in industry or in commerce; the result is, to re-quote a portion of the Report given on page 4, "the men work slowly as long as the job produced is on time rate so as to obtain the fixing of a higher piece-work rate." Observation of a casual character cannot be expected to ensure the best results.

Another type of observation might be termed mechanical observation. What is meant by mechanical observation is to record accurately the time taken from the start to the finish of an operation without taking any steps to see that the methods, tools, speeds, feeds, and depths of cut used are such as to make efficient results possible.

It is probable that no firm would be willing to admit that such a practice is followed, but it is necessary to remember that the arrangements of management are not always carried out as intended; and that, further, so long as staffs are chosen for their abilities as craftsmen only, and are given no training in the duties they are to undertake, such inept occurrences as mechanical observation will not be uncommon and must be expected.

The responsibility for this, however, cannot always be charged to the inability of staff. In certain parts of the country the practice has been to employ clerks to " observe," and to fix job rates on the results of that observation, and so common has this practice been that to employ craftsmen to do the work, excepting, perhaps, in the case of the departmental head, has been looked upon as unique. While argument is hardly necessary to prove the futility of the practice, three examples will indicate the direction in which the weaknesses are to be found.

A brass finisher had two articles to turn, there being approximately 1 hour's work in each. Two spigots had to be made, however, as well as a special tool, and the time taken for the spigots, tool and the operation proper was 5 hours. This was interpreted by the

EXAMPLE OF FAULTY PRACTICE NOT DISCOVERED UNDER OBSERVATION

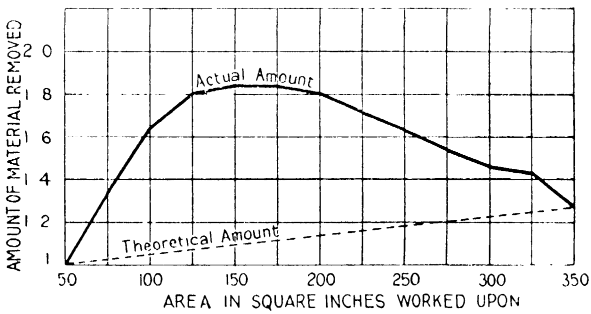


FIG. 14.

In a highly competitive business, it was desired to establish a firm basis for estimating, and instructions were given for a series of observations to be made which, after the elimination of weaknesses, would enable this object to be achieved. The observations were duly made and the results were tabulated and applied in the building up of estimates for tendering purposes. The observers came to the conclusion that there should be a slight but steady increase in the amount of material removed as the area worked upon was increased, and it was held that this increase was reflected by the factors per square inch decided upon. No attempt at analysis or comparison was made and the factors were given in terms of feed per square inch × square inches. Converted into terms of material removed and treating the smallest amount as 1, the comparison of the actual amounts removed as per the tabulated factors and the theoretical amounts for the removal of which the observer felt he had allowed is as shewn.

clerical observer as 2½ hours per piece, and time and a quarter was paid, the job rate under the Rowan system being 3 hours 20 minutes. A few weeks later, 30 of these articles were required to be machined, and the job rate allowed previously (3 hours 20 minutes) was given, to the workman's consternation as well as amusement. He contented himself with saving half the time and the job rate stood. Actually, on the basis of 1 hour's work, the job rate should have

been 1 hour 20 minutes each, the time spent in making spigots and tools having nothing to do with the operation itself and should have been allowed for separately.

In another case the milling of 3 keyways, 30 inches long, was carefully "observed," the time taken being 4 hours, the job rate being fixed at 6 hours. So soon as the "observer" had fixed the job rate, however, and had left the machine, the feed was increased and time and a half was possible with time rate efforts. The third example is an illustration of the inconsistent results which can be obtained by observation and accepted as satisfactory. See the diagram on page 125.

Analytical Methods, Observation and Estimation. The next and most useful kind of observation is that which may be described as analytical observation. In America this is termed motion study, and has been developed to a much greater extent than in this country. Dr. F. W. Taylor first gave real voice to the possibilities of analytical observation, and his work, possibly more than that of any other man, is responsible for the attention given to the possibilities of the efficient use of the workers' energies.

It is unfortunate, however, that some of Taylor's successors should have fastened on to the undoubtedly valuable idea, and, with all too little knowledge, have recommended motion study as the one thing needful until they have succeeded in excelling the payment by results extravagance which has been a feature of some ill-balanced enthusiasts in this country.

The value of motion study in its proper place cannot be exaggerated, but the field is a restricted one. In many respects all men are motion students. No man deliberately does things in the most laborious way, and the short boy who tries to counteract his lack of inches by standing on a block is merely following a natural desire to make his work less difficult.

By analytical observation is meant the examination of the different movements necessary to complete an operation; of the tools used and the rate at which each movement is carried out, the object being to call attention to and remove any weakness which may be disclosed. Thus, given the knowledge that a cutting speed of 100 feet should be obtained, anything less than this would call for attention; if the feeds required are 20 to the inch and nothing better than 30 can be obtained, there would be a reason which should be ascertained; and so on, with depth of cut and other matters. The reason for any deficiency would need to be traced and the requisite remedy applied.

Very real and, indeed, wonderful results have been obtained from the use of analytical observation, and it is not unlikely that the objections which have been raised to this method are in some respects a measure of its success. It is stated that pain and distress of mind to the person being observed cannot be avoided under analytical observation, but, in too many cases, this has been caused by the knowledge that one of the results of the records taken would

be to show up the previous low rate of output. At the same time, if the work be unwisely handled much harm can be done and nervous people can be distressed.

Great tact and consideration are necessary in making observations of this kind, and, where the policy is adopted, it is advisable and but reasonable that it should be done as far as is possible as a joint effort by the observer and the observed. It should be the carrying out of an operation ; the behaviour of the machine, the efficiency of the tools used, not the worker that is being observed. The author has made many observations and has often found that, treated in this manner, the worker has put as much interest into the job as he has himself, and he has actually had to restrain some because of their eagerness.

In the case of the turning of a large steel worm-wheel, the rate of output obtained was not in accordance with that estimated ; the estimating of rate of output is dealt with later in this chapter. The reasons for this were not apparent, and there being a large number required it was decided to observe the operation being done. The turner, an impulsive chap, was quite upset, and in his fulminations gave the clue to some of his difficulties. It was put to him that the records of the time taken, as they stood, went to indicate that he was either slow or indolent ; but that it was not the firm's policy to accept records blindly and it was desired to ascertain the real reason, to see whether this was due to the machine, the tools or the man. Immediately there was a change in the man's attitude. He said he had been expecting trouble, but instead was going to be given an opportunity of demonstrating his difficulties. He did, and it was speedily evident that the lathe was too small in the bearings to carry the job satisfactorily, undue chatter being set up. Another lathe was used, when the man gave the rate of output estimated. It was plain the records, as they stood, were not fair to the man, and he was much relieved as a result.

The question which has to be decided is, to what extent analytical observation can be applied with economical results, and if these be of short range what is the alternative?

It will be obvious that analytical observation must cover every movement necessary to the completion of a job, although this does not mean necessarily that the whole of an operation must be observed, or, on the other hand, that an observation which refers to one piece only is sufficient. Both the nature of the work and the quantities being worked upon are important factors. Operations usually consist of cutting and handling—this applies to fitting as well as to machine work—but where machine work is concerned the actual cutting is not affected by observation : the machine does not cut faster because it is being observed ; what matters is that the cutting being done shall be done at the correct rate, and this is a question of specification rather than of observation.

It would follow, where the amount of material to be removed takes sufficient time to enable other work to be done by the observer,

that no good purpose could be served by the observation of cutting, and that, after seeing that the right speeds, feeds, and depths of cut are being used, or specifying what should be done, calculation would enable the total cutting time to be arrived at. This fact, perhaps, is not always sufficiently appreciated, and arguments advanced against analytical observation have been used which have had as their basis the folly of watching " long " cuts and the accompanying cost.

Possibly such waste of time has occurred, but this reflects the mentality of the people concerned rather than against the principle. What, perhaps, is the stronger argument is that when cutting takes up much the larger part of the total time, that saving which is possible as a result of analytical observation, may be so small as not to be really worth while, although, by itself, this is not sufficient. If efficiency is to be the aim, reasonably accurate knowledge of the time value of the handling is as necessary as that of any other item, and this becomes the more important as the quantities to be handled are large, and as the proportion of the handling time to the cutting time is greater.

Where operations of short duration are involved, such as small capstan, drilling and milling operations, more particularly where the feed is sensitive or hand-feed, analytical observation becomes of real use, and in some instances may be essential. The same may be said of certain fitting and assembly operations ; some of these are practically all handling, and while it is not impossible to deal with the time required for their performance by other means, analytical observation is often found to be most satisfactory.

It would be unwise to state an opinion as to the extent to which analytical observation is necessary until alternatives had been considered. The possibility of confining observation to essentials has been made apparent, and when the removal of material is concerned it will be obvious that calculation is much more economical than the most restricted period of observation. If, for example, a planing operation be considered, an observer should know the cutting capacity of the tool steel on the material being cut ; the depth of cut, the rate of feed, and the cutting speed. If the capacity of the machine were not known he should have a test made to ascertain it and once this has been established, the job in question would require no more attention so far as the ascertainment of the cutting time may be concerned.

The cutting capacity of the machine being established there is no need for further observations to be taken ; the machine can be relied upon to repeat the performance on the same and other jobs, and calculation should always be possible and prove satisfactory. This leaves the question of setting and handling untouched. Experience, however, shows that this is always a variable quantity, and that the time observed to be taken on one piece will not necessarily be precisely repeated on another piece. This being so, absolute accuracy can be only obtained by observing each piece set,

and this, obviously, is not a practicable proposition, if for no other reason than that of the cost of doing so. Then if the observation of the setting and handling of one piece or all pieces on one batch provides nothing better than an approximation, it is not illogical to suggest that an estimated approximation based on the results of analytical observation will be satisfactory if generally applied, and that by so doing the need for further observation will be obviated.

Thus the changing and setting of a piece of work involves the lifting of the piece from the floor to the machine either by hand or by the use of crane or other lifting appliance. The packing-up or setting into position, and the gripping either by chuck, vice, or bolts and clamps follows. Each of these items will be dealt with in its respective sequence and can be observed, and the time taken duly recorded. Using carefully trained and practical men it is possible to use analytical observation for the purpose of building up data for use with all classes of work, thus applying, to a considerable degree, the advantages of analytical observation to jobbing work. By job rates would then be set a standard of output, something to be achieved, as against the datum line of improvement set by the records of the time system or by mechanical observation.

For the estimating of the time required in its performance, hand labour operations are of the same uncertain nature as is the setting of pieces on machines, and it is held in some quarters that it is impossible to estimate for fitting and similar work. While there are difficulties, yet logically the argument has no foundation in fact.

Let it be assumed that the job rate for a fitting operation has been based on the records built up by the work done by "A," "A" being reputed to be a man of average ability. Leaving out of consideration the fact that a man whose ability on one type of job is of an average quality and on others may be good in one case and poor in another, for job rates to be based on the ability of one man is to provide a rate which will be fair for that man but may be either low or high for other men, and not necessarily be a fair rate for the job. The job rate fixed will reflect the time taken by that particular man's performances—nothing more. Hand work can be dealt with more effectively than this. Take, for example, the tapping of holes, the chipping of faces, the scraping of faces, riveting, and so on. There is no virtue in observing the tapping of ·75 inch diameter holes over and over again. If under fair conditions it be known that such a hole 1″ through can be tapped in 5 minutes, a good square job being the result, then this is satisfactory and less costly than the repetition of what must become mechanical observation. And so with scraping and riveting; standards can be built up which enable close estimates to be made as to rate of output, each item really embodying the advantages of analytical observation, and being applicable to new jobs, removing thereby one of the difficulties referred to in the Report quoted on page 4. An important point is that the work of neither the quickest nor the slowest men should be used in building up the data required.

One of the chief advantages to be obtained in estimating the time required to carry out any piece of work is the impersonal nature of the process. Once the data has been collected and passed for use, the fixing of job rates is removed from any consideration of the workers' willingness or ability to produce, and tends to establish a standard of performance, the moral effects of which can be far-reaching.

In the case of job rates fixed in this way being questioned as to their sufficiency, then with machine work it is a question almost of absolute proof ; the machine will or will not remove material at the rate laid down in the estimate ; if it ought to do and will not, the fault is with the machine and not the man. If hand work be involved the matter is not so clearly a case of absolute proof, although here certain performances have been proved to be possible, and again, there being definite knowledge as to the conditions under which the work was done, from which the data was obtained, and also of the conditions under which the operation which may be in question is being done, definite comparison is possible and the reasons why can be ascertained.

Again, when, as not infrequently happens, the material is harder than should be the case and speeds have to be reduced accordingly, or forgings or castings have more material to be removed than estimated for, more cuts being required in consequence, allowance can be made in the full knowledge that to do so is correct. The more accurate the knowledge existing as to the basis of job rates, the more readily can special conditions be observed and allowed for ; also the more knowledge is there disclosed as to the existence of difficulties.

It has been argued that faulty organization or shortness of work should not be allowed to affect job rates ; while this is correct, yet, so far as the worker is concerned, he must be allowed a job rate in some form or other, which will cover the work to be done under the conditions obtaining, however unsatisfactory such conditions may be, or the work should be stopped at once. The worker who is under instructions has no responsibility for conditions, and, in equity, must be suitably allowed for carrying out the work given him to do. The recommendation is in no way illogical and in its tendencies is much to be desired.

When job rates are based on records or fixed without analytical treatment, the conditions existing are rarely detailed and temporary adjustment for special circumstances is both difficult and dangerous. The need for such adjustment is not always recognized and, the adjustment not being made, loss to the employer or injustice to the worker can follow accordingly as job rates ought, in equity, to be decreased or increased. Under a basis of analysis the position is safeguarded, and the setting up of a known standard necessitates that departure from such standard, up or down, should be recognized and allowed for.

To do so, even should such adjustment be always in an upward

direction, is to encourage the workers to call attention to special conditions; for example, if forgings are being received heavier than is necessary, involving waste of material and also time in the removal of the excess material, then while an allowance may be made—independently of the job rate proper—attention will also have been drawn to such waste, and this enables the necessary action to be taken to prevent further waste. Similarly with faulty machining which is causing additional work for fitters: in the job rate should be allowed time for the normal work of the operation, and anything additional should be treated as special, and extra time allowed accordingly, the reason for same being stated. The amount, causes and cost of such allowances can be readily made known, the tendency being always towards their elimination, and by being handled in this way the eventual cost per piece will be less than as though the allowances were hidden in the job rates. It is desirable, of course, that the necessary steps be immediately taken to remove the causes and, thus, the need for allowances to be repeated.

Where an investigation appears necessary because of apparently low output (see Example No. 1, page 14), analytical methods as described will be found of great use. An accurate measure of output independent of records is one of the crying needs of to-day, and it is safe to say that without this knowledge, production policy, where rate of output is concerned, must be blind, and real control must be a matter almost of impossibility. Because of the lack of this standard the old policy has been weak, unsound and often unjust. On the one hand, men have deliberately malingered over their work, thereby prejudicing the well-being not only of the employer, but of the industry and, therefore, themselves; while, on the other, workers have been discharged because some official thought, without having any proof, that more work should be done than was possible.

A number of cases have come under the author's personal notice where instructions have been given by the management for men to be discharged on the grounds of low output, and intercession has been made and proof advanced that the men concerned were not blameworthy.

From every point of view, efficiency, equity, control and cost, a standard of performance is to be desired. In the laying down of a new plant, it is as important to know the number of machines required as it is their types; by that knowledge the lay-out can be prepared with some certainty as to the most suitable position; economy is also ensured from the standpoint that not only will unnecessary machines not be purchased, but that those which are purchased will be as closely in balance as the conditions allow.

Again, in the regulation of production and the making of promises, adequate knowledge is required long before "average" rates of output can be made known. Programmes are required and the planning of work for certain machines may have to be done months before manufacture is commenced.

Still further, reliable estimates of the possibilities of output strengthen the hands of management as regards the shop supervision, and of the shop supervision as regards the workers under their control, by providing them with a standard of comparison which has been based on known facts and which calls for performances which are possible.

CHAPTER XII

COLLECTIVE SYSTEMS AND BASIS OF PAYMENT

Collective systems, generally speaking, are not nearly so well defined as are the individual systems. The use of the collective principle has not been general, and it was not until during the Great War, when some firms found themselves in difficulty as a result of the poor administration of their individual systems and some means of extrication had to be found, that attention was directed towards alternatives to the individual system. Some of the means adopted under the guise of collective systems have had no more influence on or relation to output than an increase of time rate would have.

As applied to engineering work, it might be said that where the collective principle of payment obtains, the method adopted differs from that obtaining with the use of individual systems, only by the extension of the job rate to include the time of operations which are independent of each other, the job rate so fixed including, perhaps, all the production operations in a workshop or perhaps of a whole works.

In one large works such a system was used. The payments made were presumed to have been based on output, but the units of product were so large that if payment had been reserved until deliveries were made, the date of payment would have been so far removed from the carrying out of a large proportion of the work as to fail to present any real inducement to workers towards putting forth the requisite effort. To overcome this it was arranged to pay 1 penny per hour to account to all the men employed. This was done and the payments were made so regularly, without any open reference being made to output, the basis of payment being unknown to the workers, that the time rate for that works was regarded by the men generally as being 1 penny per hour more than that paid elsewhere. This worked prejudicially to the interests of other firms in the district by attracting their men, and this latter constituted the only advantage the firm gained from the use of the system. The practice was popular with the Trade Societies, representatives of which, although against the principle of payment by results, signified the willingness of their societies to its adoption, and, in one works, one firm was asked to instal the same system,

the Trade Union delegate saying the firm could make the basis what they liked.

In another works a bonus of £5 per machine was paid, irrespective of any minimum number of machines turned out or of the number of people employed or of the hours worked. In such circumstances efficient results could hardly be expected, and the system was abolished and replaced by one of the individual systems under which the output was doubled. This example is cited as an indication of the lightness with which schemes of this kind are sometimes adopted, rather than as an argument against the use of the collective principle. Much better arrangements are possible than these, although the arrival at a basis in the nature of things must be either a shot in the dark, an acceptance of existing conditions, or it must entail immediately a somewhat difficult and prodigious set of calculations.

From the standpoint of the recognition of first principles the basis fixed should be such that comparison with the output obtained will reflect, fairly accurately, the efficiency of the efforts put forth and at the same time will not prejudice the obtainment of efficient costs. This point is one which can hardly be over-stressed, because production at economic costs underlies the whole commercial structure, and the failure to ensure this has been the cause of much of the industrial trouble experienced.

While it is the author's opinion that by the use of the collective principle the approach to efficient output will be not nearly so certain or so near as is possible under individual systems, it would be wrong to suggest that efficiency either of output or cost is impossible under it, if only from the point of view of production control, and the knowledge that, with suitable control, efficient output is possible even under the time system ; possible under it, but not assisted by it. What, then, is possible under the time system must, of course, be possible under any system of payment by results, and should be more easily obtained thereby.

Ideally, the basis of payment should be the time value of the job ; that is to say, if steam engines are to be manufactured and the time value of one engine is 5000 hours, the time in which each engine is turned out, or if, as is likely to be the case, the output is averaged, the average time per engine should be compared with the 5000 hours and any extra pay made be based on that amount. Excepting the existing rate of output be taken as the basis of remuneration or job rate, it will be appreciated that treatment of an analytical character will be called for. This would enable a fair standard of efficiency to be set, and as set out in Chapter V. this is regarded as essential in the best interests of the industry. Where this method be followed and the records of individual output be put to suitable uses, with the object of keeping the individual efficiency up to the standard fixed, good results may be expected.

One of the supposed advantages of the use of the collective principle, the levelling of reward, could be obtained by giving a job rate for each operation done during some specified period, as a week or

month, and to pool the results, dividing the extra pay which may be earned in the manner arranged ; this, however, would be to lose one of the advantages of these systems for which much is claimed.

This claim is that the efforts of each individual worker are directed toward the preparation of those items which will shew up immediately in finished product, and there is no doubt that the experience will have a trend that way. Bad organization and inefficient supervision can be counteracted to a considerable degree by the undoubted knowledge of requirements possessed by the workers, but, as argued previously, it is not good business to embody the cost of overcoming these weaknesses as a permanent item of future costs, and this feature of collective systems cannot find expression to any appreciable extent excepting where such weaknesses exist ; therefore, it is the price a firm elects to pay its workers for their assistance in doing what their management has failed to do, and this view of the situation has been tacitly accepted by advocates of the use of this method of payment.

Failing this detailed estimate of the time value of the product, some other basis must be used, and that most often adopted is the amount of output actually being obtained in a given time, in terms of money value, weight or quantity. The suitability of either of these will depend to some extent upon the nature of the product. Thus, when each part is machined all over, weight could be, for practical purposes, as accurate a basis as numbers, provided the relationship between material and labour were maintained, and if more than one class of material were used that the proportions were not affected ; but, excepting weight be the factor which actually controls output, such a basis could be logically used only when its relation to the controlling factor became known.

Thus, if a heap of coal had to be moved by the use of a shovel from one position to another, then inasmuch as weight or volume is the controlling factor, so would weight be the appropriate basis on which to value the work done, but if the manufacture of machinery be in question, then, because labour is the controlling factor and weight gives no direct, nor necessarily any true indication of volume of output as affected by labour, weight is not the appropriate basis and can be used safely only when the relationship of labour, the controlling factor, with weight, the convenient factor, has been established.

The position is similar where the basis used is that of numbers. Numbers alone do not convey any idea of the labour value of the work done. An engine of 1 horse-power counts one just as does an engine of 1000 horse-power, and it is necessary that, once a basis is fixed, the numbers manufactured should be continued in the same proportion. If this be not the case then any change made in the quantities of a given type can and is likely to upset the illogical basis used, either in favour of or against the workers, and alternatively, of course, the employer. Only in those cases where weight and value of labour rose or fell in the same proportion would

the potential basis remain the same ; in all others, in a greater or lesser degree, the actual basis, judged from the standpoint of opportunities for earning, would be raised or reduced by virtue of such disproportion. Consideration has been given to using horse-power as a basis where engines are manufactured, but the varying relationship of horse-power and labour has caused the idea to be dropped.

A difference in design can also affect the basis. It is quite a common feature to find that certain parts of a machine require strengthening, having either broken down or given unsatisfactory service. No difference whatever may be made to the amount of work involved, but gradually the weight can be increased. On the other hand, the employer who finds his basis is too high will probably follow the examples of those who use the individual system and adopt other methods so as to justify altering the job rates as, say, to attempt a reduction by reducing the weight without affecting the amount of work required. Such considerations appear petty, but the references are to actual and not infrequent happenings which may recur.

An example of the unwisdom of the use of a wrong factor is to be seen in smithy work. In some cases smiths are paid so much money per hundredweight of forgings turned out, and it is known that the forgings from a smithy where this method of payment is used are always heavier than need be. The inducement is to deliver weight, not pieces.

The value of the work turned out is used in other cases, the total wages paid per month being compared with the selling value. As the proportion of wages per pound of selling value decreases the extra payments made monthly are increased. There is an advantage in the scheme which is not obtained with others, inasmuch as interest is excited thereby, in the economical use of material as well as the efficient use of time. In a competitive business where the selling prices are influenced by commercial considerations as well as those of actual cost, a scheme of this kind is more deserving of consideration than where weight is the basis when the tendency for pattern-maker, foundrymen and smith is to leave as much material as possible. The objection, of course, in a case of this kind, is that output can be affected so much by policy. There are firms in the instrument trades who manufacture parts for stock years ahead, and these being in the shape of parts only do not shew up as saleable output. With a proviso to meet such a case there is real merit in the arrangement so far as a collective appeal to the individual can be truly successful. At the same time, it must not be overlooked that this arrangement can be sound only so long as the proportion of wages to selling output remains the same. Any change in the proportions of material to labour will affect the opportunities for earning and the cost of the work, either up or down.

The safer and more logical plan is to adopt a system of output units, such units to reflect the wages or time value of the different jobs in question ; in the absence of estimates which could be used

for the purpose or of the facilities for providing the information required an opinion based on experience or records must form the alternative. Then it would be possible for the nature of the product and the quantities manufactured to be varied without interfering with the rate of remuneration. Similar methods for these have been in use in connection with the staff bonuses for years and have given satisfactory results. (See Chapter XIII.)

Time Worked. While it cannot be too strongly emphasized that the only logical basis for any system of payment is that of the effective factor, it is of the greatest importance, whatever basis may be used, that time worked should be retained as a controlling factor in the computation of any extra payment which is to be made. Failing this provision, the operation of collective systems, where output is concerned, is likely to become somewhat farcical. Instances have been cited demonstrating this fact. In this respect hours worked are a better basis than the number of people employed, being a protection to the workmen where, through sickness or other reasons, time is lost, and a safeguard to employers against the abuse of overtime. The names of 100 people may be on the books, and 100 people may actually have recorded time in a given period, but if the total hours worked in the aggregate be equal to 95 full weeks or months the appropriate factor would be 95 rather than 100, and the output per hour would actually be greater than would appear if number of persons only were used in the computation. Conversely, if overtime were worked, say 5 hours per person per week, then although the actual number of people employed would remain the same, in effect, the overtime would be equal to an increase of personnel of 10.6 per cent.

Minimum Output. It is most desirable that a minimum output should be given before any extra pay becomes due, otherwise additional wages could be shewn as earned when but one-half the amount of the work possible was being done. Where the system is introduced into a works which has already had an output such a warning is unnecessary, but in the starting up of a new works, in the anxiety to obtain output, the collective principle has been adopted and a price per article has been fixed. In the war period this was often done, and there are many cases where the extra pay was much greater than the time wages, although normal output only was being given. To aim to get output is to pursue a right policy, but the obstacles standing in the way of production are not necessarily removable by the workers, and low output may not reflect discredit on them, and any resultant increase in output which may be obtained subsequently will quite likely not be due to increased energy at all.

One system to which considerable prominence has been given is known as the " Priestman " system. This system was started by Messrs. Priestman Bros. of Hull, with the object of increasing production, and its basis was that as output was increased over an agreed standard the wages and salaries of all employees was to be

increased in a similar proportion. The unit of measure on which the standard output was fixed was tons of cranes, etc., completed, and the standard was arrived at by taking the weight of the total output for the six months immediately preceding the starting of the system, the hours worked being taken into consideration.

In addition to this Messrs. Priestman gave a voluntary increase of wages of 10 per cent., for the purpose, apparently, of inducing their workpeople to accept the method of payment proposed.

From the one standpoint of increased output the results of the operation of the system have been fairly satisfactory, bonuses varying up to 50 per cent. having been paid, indicating that output had been increased in a similar proportion. It will be apparent, however, that the cost of labour has been stabilized on that previously obtained plus 10 per cent., and that this being so, excepting such costs represented efficiency in the sense that efficiency is achieved by crane makers, the costs following the working of a system so based cannot be looked upon as being satisfactory, and are likely to make the meeting of competition more difficult or to induce competition by the opportunities made available through selling prices being too high, the natural sequence of high costs.

The situation is worthy of analysis for the purpose of guidance in other directions. If it be assumed that the standard output per week be 100 tons, and the cost of materials and wages and the amount of oncosts incurred be £10 per ton in each case—£30 in all—and if, of the £10 oncosts, £4 represents salaries and indirect labour subject to increase *pro rata* with production, the results of obtaining increased outputs of 20 per cent. and 50 per cent. as shewn by the costs would be as follows :—

System in Use.	Weekly Output.	Value of Material.	Wages and Extra Pay.	Oncosts.		Total.	Cost per Ton.
				Salaries and Wages.	Other Expenses.		
Time - -	100	£1000	£1000	£400	£600	£3000	£30
Priestman Collective	100	1000	1100	400	600	3100	31
	120	1200	1320	480	600	3600	30
	150	1500	1650	600	600	4350	29

The result of output being increased by 20 per cent. will be seen to counteract the 10 per cent. increase in wages, while an increase of 50 per cent. in output shews a reduction in total cost of 3·3 per cent. It needs no argument to point out the dilemma in which a firm would find itself in stabilizing its future costs in this way, particularly if those costs did not represent a reasonable degree of efficiency.

It will be recognized that the voluntary increase of wages of 10 per cent. given by Messrs. Priestman is not an essential requirement of the system. It was done by them probably to get over some

local or temporary difficulty. The action taken was undoubtedly an unwise one, and will have helped to counterbalance the influence of increased output in the direction of reducing oncosts.

Another collective system which was used during the war period in connection with the manufacture of fuzes is described below.

The Works Manager was not in favour of the individual system, being keen on the use of the collective principle. The standard adopted was 11,000 fuzes per week, and the conditions under which payment was made were as follows :—

1. On work accepted by the Government Inspectors.
2. On actual hours worked.
3. At plain time rates, excluding war bonus.
4. Provided the average output per week does not fall below the standard output of 11,000 per week.
5. Provided the number of employees is not increased by more than the following percentages.

For an output of	11,000 to	14,000	fuzes	per week.	No increase.
,, ,,	15,000 ,,	19,000	,,	,,	3 %
,, ,,	20,000 ,,	24,000	,,	,,	5 %.
Above	25,000		,,	,,	10 %.

6. In the case of careless work on the part of any individual or groups of individuals the Management reserves the right to reduce or stop entirely, for the period concerned, the extra pay otherwise due.
7. The provisions in the scheme are based on those conditions of manufacture obtaining at the present time, and will not be altered excepting definite changes are made to the plant or the design of the fuze now being made.

Under the operation of this scheme, the payment being calculated on the Halsey-Weir principle, the output was increased to 20,000 fuzes per week. On a class of work such as fuzes, one type only being manufactured, efficient output to a great extent can be obtained by good organization, a suitable supply of tools, and attentive and efficient machine-setters—much more so than in the case of ordinary jobbing work, because supplies of parts of each kind are continually required, and shortages or accumulations can be readily noticed.

Starting up New Products. The starting up of new products presents a real difficulty in the use of collective systems, when payment is based on the amount of finished product, and this difficulty is the greater as the unit of product is a large one. Such experience is likely to be found with a firm which has no standard line, or where, as with marine engineering, changes of design and size are necessitated by the requirements of the shipowner's business. In some cases, for these reasons, deliveries are intermittent and fluctuate largely in value, while with entirely new products, excepting their value be estimated or "jumped," no basis can be fixed until the work has been completed. If no basis be fixed the whole

scheme will be upset, the operation of the system being virtually suspended.

It is known by employers, and has been pointed out by workers, that more men are required in the earlier stages of manufacture than during assembly, and that when a job is nearing completion a reduction of hands often follows, so that whatever amount of payment may be due as a result of delivery being made, a smaller number of people would share than were employed when the major portion of the work was being done. This is correct and, if not provided for by arranging that the records of time taken shall be looked up, for the periods in question, would make for serious discontent because of its unfairness. In such circumstances payments due ought to be made even to men who may have left the firm's employ.

A review of the facts goes to shew that there are difficulties with the basis of payment for collective systems as with those of an individual character. They are of a different nature but are none the less real, and excepting the arrangements are made with a considerable amount of circumspection and are frequently reviewed it will quite likely be found that although started off on an apparently satisfactory basis, changes of one kind or another have taken place which will materially have altered the conditions originally laid down. The practice of using factors which have no true relation with effort, for the purpose of making payment for the efforts put forth, cannot be held to be satisfactory, and is likely to cause difficulties to arise at some time or other. At the same time the greatest difficulty of all is that of fixing a truly efficient output rate which, being based on a real knowledge of the time value of the work involved, would enable the weaknesses to be avoided that have so marked the administration of individual systems.

CHAPTER XIII

STAFF, INDIRECT LABOUR AND PAYMENT BY RESULTS

THE question of the applicability of payment by results to members of staff and to certain classes of indirect or secondary labour was discussed in Chapter IV., when it was shewn that it was not practicable in the ordinary way to instal a system of payment by results in certain sections of the works and to expect that those sections which were left outside the operation of the system would be unaffected. It was also pointed out that although some provision was necessary in the shape of increased wages in order to maintain or restore the balance of same there were distinct advantages to be gained in making such payments depend upon results; but emphasis was laid upon the desirability in the interests of efficient progress and cost of making sure that any payments which may be made would reflect with reasonable accuracy the true efficiency of the work of the people who were to receive them.

In the desire to regain the balance of wages lost through the introduction of payment by results to sections only, there is sometimes a predisposition to make this the chief aim and, if the formula arrived at is one which will ensure that the payments made are not too large, to consider that an efficient arrangement has been made. It is a better policy, however, to consider that the principle of payment by results is applicable to many grades of labour, and that while it is necessary to maintain the balance of wages, it is possible in doing so to get real value for the additional money which may be expended. The underlying aim must be efficiency and economy of production rather than payment; payment in some form will be necessary, but the basis of the payment is the important point.

There are four main classes of workers to which a system of payment by results cannot always be efficiently and conveniently applied.

1. Supervisory staff, whose duties require them to organize, to give instructions and to control.

2. Machine-setters and sundry skilled workers, who receive instructions and are responsible for setting machines or keeping them in a condition suitable for running.

3. Inspectors, who are responsible for the acceptance or rejection of pieces accordingly as they conform or not to a standard laid down or understood. There are classes of work and circumstances where inspectors are paid under an individual system of payment by results, but the attendant risks, owing to inspection leaving no indication of its having been carried out, are found sometimes to be too great to be taken.

4. Labourers, crane-drivers, slingers and the like, who receive instructions, have general duties, no responsibilities, and are often but intermittently busy.

Dealing with the supervizory class first, the efficiency of foremen is affected by several factors, and it is desirable that efficiency in every direction should be secured. A foreman should be a good technician; he should also be able to organize efficiently and to control effectively. The results, when each of these factors is in satisfactory operation, would be economical and efficient production in a minimum of time, within the limits of the plant and the quantities available.

It will be apparent that to base payment on one of these factors only would be to give a special significance to that one, to the detriment, possibly, of others. For example, if efficiency of the product were to be the only effective consideration, and extra pay could be secured by that achievement, the results would be little better than as though an increase of wages had been given. Cases are known where a stated amount has been paid per machine turned out. If large numbers of machines were on order, then the faster the rate at which the machines were turned out the more quickly would the payments for the whole of the machines become due; on the other hand, a fall in output, whether due to inefficient supervision or to shortness of work, had no effect on the total amount of money paid; the period over which the payments were being made was merely extended. Thus, an order for 100 machines, for which a bonus of £5 per machine was paid, meant that a total bonus of £500 would be paid sooner or later. If trade were good and the machines were finished in six months the money would be paid during that period at the appropriate rate; if, on the contrary, the time taken to deliver the machines were extended to two years, £500 would still be paid. A bonus of that kind is a certainty, and certainties have little inducible power.

A worse example is where a stated sum, per foreman per machine turned out, is paid. In one works this was done, and as the demand grew other work was gradually dropped. The plant was steadily increased, outside help was obtained, also gradually; the number of foremen also was increased, until the combination of circumstances was such that the extra payments made on the basis of output were greater than the salaries paid and quite out of proportion to the value of the work done.

Another method in fairly common use is to make the basis of payment that of the average percentage of extra pay earned by the

people supervised. Thus, if a foreman supervized 30 workers, and their average earnings exceeded time wages by, say, 30 per cent., the extra payment such foreman would be paid would be a sum equal to or based on that percentage.

Superficially, this method may appear to be sound. There is little room for doubt that if the earnings of workers are increased under payment by results, output will be increased also; at the same time, a most dangerous weakness exists, independently of whether the basis on which job rates are being fixed is good or bad. If there were no such thing as human nature, or if human nature had no frailty; if human skill, the capacity to produce, could be standardized, and the time value of every operation were fixed with mathematical precision and was always accepted without complaint from workers, the weakness referred to could disappear, but such a state of things not being possible some differences of opinion as to the sufficiency of job rates will arise, and compromise is often unavoidable.

Now, while increased earnings can reflect an increase of output, they can also be the result of job rates being too high, in which case earnings can shew an increase although unaccompanied by an increase in output. Thus, to make extra pay to depend upon earnings is to make the size of those earnings a primary object, and the foreman's interest is directed to this end. No one would dream of arranging that a rate-fixer should be paid additional salary, the basis of which would be the extra pay earned by men on the job rates he had fixed; such would be a direct inducement to the fixing of high job rates. This is so obvious that argument is not needed, but it is necessary to make sure that this influence is avoided in every direction.

No person other than the worker himself should have any interest in high job rates. Ordinarily, the foreman has no such interest; the responsibility is not his, but while this is so it is a common and desirable experience that workers who think the job rates offered them are too low should seek their foreman's advice thereon. In the majority of cases the foreman's opinion will be honestly given; but the fact that honest decisions may affect his weekly earnings is not good, and there are many instances where the dependence of the foreman's extra earnings upon those of his men has been allowed to prejudice the opinion given and has led to job rates being raised without justification. The influence is in the wrong direction and is bad.

From another standpoint, too, there is a weakness. One of the tests of a foreman's efficiency is that of good shop organization. A good organizer will arrange to produce parts in those quantities which will enable complete units to be assembled and delivered. Under the percentage basis of payment this interest is not encouraged, attention being directed to operations only, and to those operations which are thought to have high job rates. In principle the percentage basis has nothing to recommend it; the trouble is

that in some industries there is no easily applied alternative, and an unsatisfactory compromise is sometimes unavoidable. This will be appreciated in the discussion of an alternative.

Seeing output is the real test of a foreman's ability, and the earnings of workers can reflect the influence of factors other than output, it is obviously desirable that, as far as is possible, output should be used as the basis. At the same time output alone cannot be accepted as providing a sound basis, because the employment of additional workers or the working of additional hours will enable output to be increased in the bulk while the output per worker could actually fall. Under the percentage method this possibility does not exist, in fact there is an objection from another direction, a common feature with arrangements which are based on the use of one factor.

The percentage system alone does not distinguish a foreman who is supervizing 10 men from one who has 50 men under his charge, and the author has knowledge of a case where work had gradually fallen away and the foreman was drawing the same percentage of extra pay as were the two men under him. The formula used for the calculation of such payments should be such that items of this kind would be taken care of.

What, then, is entailed in the provision of an output basis ? On the one hand there must be some common unit of measure ; if the product be of one kind and size and sufficiently small that deliveries can be made at frequent intervals there would be little difficulty, but accordingly as the actual conditions differ from this so will difficulties creep in. Thus, where large ships or power sets are concerned, there may be no difficulty with variety of product, but the deliveries made would be at such long intervals that the appeal made to the worker or foreman would be ineffective. On the other hand, where many different products are manufactured neither quantity nor weight would necessarily be an accurate guide, and a common basis would be necessary. Such a basis, however, can be fixed by using the estimated wages or the time value of the various items manufactured against which, for extra pay calculations, could be set the actual time taken or the money expended for the same period. This would effectually safeguard the firm from making extra payments which may be due to an increase in the number of people employed or of the hours worked, and, if the wages value were the basis used, the importance of obtaining value for money as well as for time would be likely to be observed. In such a scheme the rate-fixer could be safely included, and in each case the interest would be that of economy of time and output and of obtaining the finished product.

To summarize, one of the objects in offering extra pay to supervision staffs should be to induce their best efforts towards obtaining the most efficient output, rate, quality and cost combined, output to be measured, wherever possible, by completed articles rather than by completed operations. That object will be satisfactorily achieved only when output rises in bulk and in volume per worker, and when

the wages rates paid together with the time taken enable the cost of production to come within that of the estimate.

Cost as a Basis. One method which can be conveniently applied to products which are manufactured in large quantities continuously is to arrange to make the extra payments on the basis of actual cost against estimated cost. This has the advantage of bringing in cost as well as output, and, where applicable, this will be found to have a most useful influence.

In considering the adoption of any system of payment it is desirable always to keep in mind the appeal which will be made to the persons concerned, and also what will be the effect of that appeal on costs of production. Dealing with the last-mentioned first, as being of the greater importance, the tendency of the use of a cost basis will be to induce a large volume of output at low wage rates, and provided this does not lead to any breach of agreement with trade societies the tendency is wholly right.

Seeing that cost is made up of items other than labour—material and oncosts—it follows, of course, that these wholly or in part can be allowed to influence the results. Economy in the use of material is obviously within the foreman's sphere of influence, whether this be in connection with the initial supply or in the avoidance of spoilt work. The basis on which material ought to be considered, however, is the quantity used ; or if cost be taken, the basis should be estimated cost independent of market fluctuations, which, whether up or down, reflect neither credit nor discredit upon foremen.

Oncosts and secondary labour should be dealt with similarly. Those items of oncost should be included the use of which is under the control of foremen, as shop supplies, light, power, machine-setting, and general labour. In a well-managed concern these figures are all taken out and reviewed so that additional work in the special preparation of such figures should not be required.

The influence of such a basis will be obviously a right one, while the restriction of the influential factors to those within the foreman's own control would be recognized as just, and, if the opportunities offered in the shape of extra pay were at all satisfactory, good results should follow its use. Incidentally, the interest, all the time, would be directed towards the completed articles—not the completion of individual operations, an important item.

In the case of articles, the manufacture of which could be completed in, say, 2 weeks, a system could be arranged as follows : labour cost only will be dealt with.

Let it be assumed that the value of the labour in an article is 1/- each ; that an average of 10,000 articles per week is delivered ; that 250 people are employed on the direct work of production, and that 10 foremen and others, in a supervisory capacity, are employed. No allowance has been made in the estimate for the payment of additional wages to foremen, and none will be considered to be due when the actual cost equals or exceeds the estimated cost.

The saving shewn could be wholly or partly divided among the

people concerned in equal proportions or in accordance with their salary rates, or, for given percentages of savings shewn, percentages on salary could be paid. The latter is the safer plan ; under the former the total savings could be so great as to be out of proportion to the amount of reward really justified. Using the percentage scheme the basis adopted would need to be on the following lines :—

Cost Each. Pence.	Percentage.	
	Saved.	Extra Pay.
12	—	—
11½	4·16	8·33
11	8·33	16·66
10½	12·50	25·00
10	16·66	33·33
9½	20·83	41·66
9	25·00	50·00
8½	29·16	58·33
8	33·33	66·66

The percentage to be paid could be either greater or less than that shewn according to the circumstances. The system of payment in use in the direct work of production would need to be considered, because when the piece-work or plain premium system is in operation there is no saving in labour cost, only in oncosts. On the other hand, when one of the sharing premium systems is in use savings are shewn in labour cost as well as in oncost. Thus, if the outputs were increased under the plain and the Halsey-Weir sharing premium systems by 50 per cent., that is 15,000 articles per week were turned out as against 10,000 only previously ; assuming that such an increased output carried extra pay of 50 per cent. to the plain premium workers and 25 per cent. to workers on the Halsey-Weir system, and that oncosts were 1/- each when 10,000 articles were being produced and had not been materially affected in bulk by the increase secured, then the relative position as regards savings would be as follows, all money values being quoted in pence :—

	Basis Value.	Plain Premium System.	Halsey-Weir Premium System.
Wages - - - -	12	12	10
Oncosts - - - -	12	8	8
Total - - - - -	24	20	18
Saving in labour - -	—	Nil.	16·6 %
Saving in oncosts -	—	33·3 %	33·3 %
Total saving - -	—	16·6 %	25 %

The percentage to be paid is a less important question than the basis of payment, and can be readily decided when actual conditions are being dealt with. It will be a useful safeguard to make a condition that the extra payment as shewn by the comparison of cost and estimate will be considered due only when the proportion of the staff concerned to that of the workers does not exceed that in existence at the inauguration of the system, that is 10 supervisors to 250 workers. Punctuality and regularity of attendance may be allowed to increase or decrease the amounts due, but a scheme of this kind applicable to any system is dealt with on page 153.

Where more than one kind of product is made but the time of manufacture is sufficiently short to enable the same method to be applied, no difficulty should be encountered. There will be more calculations necessary, one for each type of product, because of the different estimated values, but nothing further. Where the articles manufactured are larger in size and take proportionately longer to produce, so long as frequent and continuous deliveries are made the same method could be applied, but the longer the period, either of manufacture or between the making of deliveries, the less satisfactory must this method become.

The question of allowing the extra pay for the different products to stand alone is a matter for discussion. As a general principle it would be better to pay on totals, but the results of the different contracts, so far as foremen are concerned, should certainly be shewn separately.

Output as a Basis. Output as a basis falls next to be considered. In the arrangement of a scheme based on output cost, as reflecting economical manufacture, is not made a factor, and some provision is necessary to ensure that payments are not made for an increase of output which is the result of overtime being worked or of an increase in the number of people employed. Thus, if the increase of output from 10,000 to 15,000 articles per week were the result of additional hours worked in overtime or of an increase in the numbers employed, no extra payments should be shewn as due, and the formula governing the amount of extra pay due should take care of this.

This can be provided for by using a standard of output per hour worked; thus, if it were estimated that 4 articles should be turned out per man-hour worked this would mean that 10,000 articles should be produced in 2,500 working hours, and the extra pay due should be based on that figure. Then, if 15,000 articles were produced in the same number of hours, that is at the rate of 6 per hour, there would be an increase of 50 per cent. On the other hand, if the increased output of 15,000 articles had been obtained partly as a result of an increase in the number of hours worked, these being 3,000, the average output per man-hour would be 5 articles, an increase of 25 per cent. only. With maximum hourly rates laid down and observed for the different classes of work, output as a basis should not be far behind that of cost from the standpoint of efficiency, although interest in economy in the use of material and shop

supplies, labour, and so on would not be encouraged. By considering an increase of output above a given standard only, rather than output alone, a minimum output is automatically called for below which no extra pay is due ; this is most desirable.

Earnings as a Basis. Where neither cost nor completed output can be conveniently used as a basis to induce an interest in the increase of output there remains the simple but objectionable one of a percentage on earnings. This can be recommended as a last resource and only where the supervision staff is concerned ; it is obvious the ratefixer cannot be allowed to participate, whereas when the basis is cost or output this is possible. One safeguard against the bad tendencies of this method is to leave the head-foreman outside the scheme. By doing this, he will have no interest in job rates other than for the purpose of inducing output, and for this purpose, in his view, high job rates are to be avoided as much as are low ones. At the same time the exclusion of the head-foreman from the operation of the scheme is a practical recognition of the weakness previously referred to. Its use is essentially a compromise between paying increased salaries independently of any reference to output and in accordance therewith. In some respects, as a matter of policy, it is desirable to pay in this manner rather than to increase salaries or wages.

Where the use of this method is unavoidable, it is necessary that a list of the shop numbers of the men working under each foreman be made out each week, so that the respective hours worked per man and the extra pay due can be totalled and the appropriate average percentage be arrived at. This last should be signed by the assistant foreman, countersigned by his head-foreman, and should be checked by the departmental timekeeper against the inclusion of numbers on more than one list.

Amount of Extra Pay. The next question is as to the amount of extra pay which should be considered as being satisfactory. This will depend in some measure upon the relation between salaries and the wages of the workers. If the salary paid be such that the balance of wages is not in question, then it would not be illogical to suggest that a foreman was not entitled to be treated as efficient until the output reached the level called for in the rate-fixer's estimates. On the other hand, where the balance of wages is involved, that is where foremen are paid comparatively low salaries, to allow extra pay to be commenced only when the average output equalled the estimated output, would be to fail, probably, in the achievement of the object.

There is little doubt that a liberal policy with foremen's salaries is more profitable than one of cheese-paring. A foreman should be a trustworthy man, and be recognized and paid as such. Being but human, no temptation should be put in his road to be other than honest ; but when salaries are low and additional pay can be secured by taking advantage of weaknesses in systems, then, while

a foreman would be wrong in so doing, he but shares the responsibility. If a worker, because of his skill and character, is considered fit to act as a foreman, then something more than glory is required; his salary should be "fore" also.

The influence of timekeeping from the standpoint of punctuality as well as regularity is a matter given prominence in some works. There is little doubt that the most important minutes of the day are those immediately after starting-time and before stopping-time. If the foreman is not there, the workers will not start work at or will cease before the correct time. To what extent this question should be linked up with output and payment for same is a question hotly contended in some works, although it is feared the value of the odd minutes is not always fully appreciated. If a foreman supervises 40 men who are paid 1/- per hour, and owing to his unpunctuality at starting and stopping-time each man loses 10 minutes per day, this is equal to 1 hour per week or 40 hours for the section; rather more than 2.1 per cent. of the whole week, £1000 per annum for every 10 foremen. To this must be added oncosts.

Looked at from this standpoint some attention is justified, and there is something to be said for linking up punctuality with the amount of extra pay earned. Sometimes the arrangement is to reduce the extra pay in accordance with the minutes lost, a specially high value being placed upon those minutes immediately following the starting-time. Deductions, however, are never welcomed, they are more often resented, and it is more diplomatic to place the basis of payment low and increase same as ideal punctuality is achieved. This can be done independently of the basis used for deciding the amount of payment due.

The number of workers to be looked after by each foreman is another question which is best taken care of by the use of a formula. It is usually left to the memory of some individual to deal with, and, as often as not, is forgotten. If not, it becomes a matter for discretion, and in these matters discretion can be a most unsatisfactory basis; so many men have "livers" or favourites. The laying down of the numbers of workers which the foremen of different sections should be able to supervise efficiently is worth consideration, the extra pay otherwise due to be submitted to a suitably arranged formula.

Thus, if the supervision of 40 workers is held to constitute a fair task for one foreman and owing to shortness of work 20 only are employed, such a foreman, nominally, is but half-employed and would reasonably expect his extra pay to be affected. If, instead of 40 workers, 5 only are employed, the absurdity of paying in full for the supervision of such a small number is at once obvious. It can be argued that wide-awake management would not allow such an inefficient allocation of foremen, but policy dictates sometimes the advisability of retaining staff even when the work in hand may not justify such retention; again, it can be argued that all extra payments to staff should be suspended when trade is bad. This

may be quite correct but not necessarily so, although even then all departments do not fall slack at the same time or to the same extent, and, even if they did, there comes the responsibility of making the decision at some stage. What shall that stage be? It means an arbitrary decision. Alternatively to stop such payments is to infer that efficient output from the workers still employed is not so keenly desired.

There can be distinct advantages gained by submitting the "extra pay" earned to the following formula:—

$$\text{Extra pay due} = \frac{\text{normal extra pay} \times \text{number of workers supervised}}{\text{standard number}}.$$

Not only are reductions in numbers taken care of as they take place, but in the event of a foreman being ill and his section has to be supervised by one or more of his fellows, the addition of the numbers of the workers, who are being temporarily supervised, to the list of the respective foreman for the period concerned would automatically carry a method of remuneration for the additional work temporarily taken on. This would help to overcome the tendency to neglect a section whose foreman was absent; this tendency is not unreasonable, because if one man is doing two men's work the efficiency of his own section is likely to suffer and thus affect his own earnings in a downward direction.

The influence of apprentices should be taken as covered by the arrangements suggested in Chapter XVIII.; no further adjustment should be necessary.

The second class, comprising machine-setters and it may be individual tool-makers or millwrights who are attached to sections for the purpose of carrying out small adjustments or repairs, is one where the efficiency is measurable directly in output. In machine-setting the skill and attention of the setter is reflected in the accuracy, the finish and the amount of work done; with a section tool-maker and millwright the quick handling of the repairs and adjustments required makes for a minimum number of machine stoppages and when such stoppages do take place for these to be of the shortest possible duration. Then, with the numbers employed being as laid down by the management the appropriate method to employ to induce the best output is to fix individual machine-setters' job rates per piece done, or to pay the three classes on the basis of the earnings made by the operators.

Whether the one method has any real advantage in practice over the other is open to question. To base the payment on the earnings of the operators is to induce an interest in high job rates, but output is the appropriate basis, and there must be some relationship between the job rates for the operator and the machine-setter. This being so, a definite relationship is likely to be established, such as the setter's job rate to be one-quarter or one-sixth of that given to the individual operator, and so soon as this is done the tendencies are the same in each case. Some allowance will be necessary to cover the initial setting, excepting a spare machine be provided.

Whichever method is adopted it is advisable to specify the number of machines to be looked after by one setter, although this should be decided according to the class of work and the duration of the jobs; a flat number of machines should not be decided upon irrespectively of the conditions. This, of course, is necessary whether payment by results is in use or not.

The calculation of extra pay would be dealt with as follows. Lists would be made out by each machine-setter, tool-maker or millwright, giving the shop numbers and names of the operators working on the machines attended by them; also the machine numbers. These lists would be signed by the sectional foreman and, if required, by the head-foreman and rate-fixer, and then be sent to the timekeeper. The hours worked by each operator together with the extra pay hours earned would be totalled, the one being given as a percentage of the other. Assuming 5 machines should be looked after, this would mean with a 47-hour week that 235 hours should be shewn as worked; then any extra pay shewn as earned should be submitted to the following formula :—

$$\text{Extra pay due} = \frac{\text{extra pay hours or percentage} \times \text{total hours worked}}{\text{standard hours}}.$$

An example worked out would be as follows :—

Jones, a machine-setter, attends to the setting of 5 machines, the total weekly hours for these machines being 235 hours. His sheet shews that the shop and machine numbers, hours worked and hours extra pay are :—

Shop No.	Name.	Machine No.	Hours Worked.	Extra Pay.
24	Smith	C 20	47	16
32	Burns	C 22	47	20
33	Evans	C 60	23	6
37	Wilson	C 51	45	12
41	Strong	C 11	40	15
			202	69

Average percentage, 34.1.

$$\text{Percentage due} = \frac{34.1 \times 202}{235} = 29.3\ \%.$$

Jones would be paid 29.3 per cent. extra pay on the hours he had worked.

In the case of a machine-setter being absent and of his work being taken over by another machine-setter in addition to his own work, his percentage would be increased in a suitable proportion by the use of this formula in accordance with the total hours worked on the machines set by him. This factor has proved most useful when

machine-setters have been away, the additional extra pay possible proving to be a good incentive. Lost time is still of importance in these cases, but the loss of time wages usually is of sufficient moment; if not, the loss of further extra pay, in addition to that which follows the working of reduced hours, is not likely to be of sufficient amount to prove to have much weight. In any case, hourly-rated men resent any but the proportional reduction which lost time automatically carries.

The difference between the sheets of the machine-setters and millwrights or tool-makers would be in the increased quantity of workers' numbers quoted; a millwright might attend to 50 or even 100 machines.

The application of either one or other of the methods mentioned to inspectors or to general labour will depend upon the local conditions. While a truly logical scheme is difficult to arrange there is no doubt that a basis of finished output approaches this most nearly, and where the restoration of the balance of wages is an object a scheme of this kind is likely to carry the least risk, while some interest in output will be stimulated, whatever that may be worth. In view of the intermittent character of labourers' work, it may be found to be in keeping with the relative values of the efforts put forth if the labourers are paid a proportion only of the average shop percentage. For example, if this percentage were 30 per cent., for the labourers to be paid 15 per cent., that is one-half only of the average percentage paid to the skilled man or to those constantly occupied.

If something of this kind were done the proportion of labourers to skilled men should be specified, the extra pay otherwise shewn as due to be subject to a formula :—

$$\text{Percentage due} = \frac{\text{percentage} \times \text{skilled men's hours}}{\text{labourers' hours}} \times \text{ratio.}$$

Thus, if 20 per cent. extra pay were shewn as due when the ratio of labourers' hours to skilled men's hours was as 1 is to 12, but the hours actually worked were 3000 hours by skilled men and 300 hours by labourers, then

$$\text{Percentage due} = \frac{20 \times 3000 \times 1}{300 \times 12} = 16.6\ \%.$$

The underlying object of the use of a formula of this kind is to induce workers to endeavour to do the work without further assistance rather than to make deductions. Failing such a safeguard a fictitious need for more help can be shewn which would make the work easier for those making the demand, leaving earnings at the original level and costs higher; with it the adjustments would be automatically made, and not at the discretion of any individual.

An example of a scheme drawn up for this purpose is given below. No special merit is claimed for it, the object being to indicate the general lines which should be followed.

SUPERVISION STAFF

PAYMENTS FOR INCREASED OUTPUT

In order to encourage and to co-ordinate the interest of the supervision staff of all grades, this term to include head foremen, assistant foremen and ratefixers, in obtaining the highest possible volume of finished output, it has been decided that additional remuneration shall be made as outlined below.

1. For the different products manufactured a unit value will be placed on each, such value to be based on the estimated time or cost, and will include percentages for machine-setting, labouring and all indirect labour under the control of the foreman. Notification of the item values will be communicated as same are fixed. Spares and small orders will be dealt with similarly.

2. The basis of payment will be completed output as indicated by
   (*a*) Acceptance by the customer's inspector at the works.
   (*b*) Acceptance by the firm's inspectors or on despatch from works.

3. The payments will be calculated in four-weekly periods, and will be based on the percentage shewn by the difference between the total unit value in hours and the total hours worked, the formula being as follows :—

$$\text{Percentage} = \frac{(\text{unit values} \times \text{units delivered} - \text{hours worked})}{\text{total hours worked} \times 2}.$$

(The division by 2 is making the scheme equivalent to the Halsey-Weir premium system. To omit this the scheme is equivalent to the plain premium system—piece-work with guaranteed time rate.)

4. In order to encourage punctuality the basis has been fixed so that the percentage will be low, but if attendance is recorded each morning not less than 3 minutes before the recognized starting-time such percentage will be doubled, and if attendance be similarly recorded for each afternoon the original percentage will be increased by 50 per cent.; that is to say, if the original percentage be 10 per cent., punctuality as indicated will cause that percentage to be increased to 25 per cent. Failure to ring in as specified will affect the increase proportionally, each morning being equal approximately to 12 per cent. and each afternoon to 6 per cent. of the total increase possible.

5. Lost time will carry with it proportional reductions. Absence with leave or when due to illness will not be counted as lost time, but the extra pay due will be based on the number of hours worked.

6. A fair number of workers which each foreman should be able to supervise satisfactorily has been fixed, and the extra pay due will be increased or decreased as the number supervised by

such foremen is increased or decreased. These numbers are as follows:—

Section A—20
,, B—40
,, C—25
,, D—30
,, E—30
,, F—40
,, G—30

7. Item values once fixed will not be altered without notice, but as improvements may be made in methods which will reduce the total hours and consequently the estimate, each new contract will require to be reviewed from this standpoint.

8. Any increase in staff which appears necessary, excepting such be the result of a proportionate increase in the number of employees, will justify a review of the scheme with a view to adjustment.

The foregoing may appear to be somewhat complicated; while this is not really so, ideal simplicity is not possible, excepting the risk is taken of the scheme running to seed—a common experience. No factor is included which is unnecessary, nor can any be left out unless a certain amount of risk is involved. If an example be taken and worked out little trouble will be experienced nor will undue time be required, particularly if the aid of tables be taken advantage of.

With a scheme of this kind the ascertainment of the percentage or the amount of extra pay due can be much facilitated if each punctual attendance be given an appropriate value or points as morning—2—and afternoon—1, that is 17 for the week. Then seeing punctual attendance at each starting time causes the basic figure to be increased by 150 per cent. it follows that punctuality, morning and afternoon, is equal to 17.64 per cent. and 8.82 per cent. respectively. A table can be built up so that according to the basic percentage and the points secured, the percentage due can be read at sight. Thus, for a basic percentage of 10, and with 15 points the percentage of extra pay due would be 23.23 per cent.

Thus, let it be assumed that the item values and output for four weeks are as follows :—

Description of Unit.	Size.	Unit Value in Hours.	No. Delivered.	Total. Value.
Fan - - -	A	20	100	2000
,, - - -	B	25	90	2250
,, - - -	C	30	50	1500
Motor - - -	No. 1	60	100	6000
,, - - -	,, 2	70	100	7000
,, - - -	,, 3	90	60	5400
,, - - -	,, 4	100	25	2500
Sundry Small Orders	—	—	—	3350
				30,000

Let it be assumed further that the hours worked for that period were 25,000; then

$$\text{Percentage} = \frac{(30000 - 25000)}{25000 \times 2} = \frac{5000}{50000} = 10\ \%.$$

Thus, 10 per cent. will be due to each foreman concerned, or more or less as his section is larger or smaller than the standard number and as his time-keeping has been good or bad; the basic percentage, in accordance with the hours worked, will be due in any case. This worked out on assumed numbers will be as follows:—

Section.	Standard Number.	Actual Number.	Percentage Due.
A - -	20	19	9.5
B - -	40	40	10.0
C - -	25	30	12.0
D - -	30	32	10.66
E - -	30	30	10.0
F - -	40	36	9.0
G - -	30	30	10.0

The figures used in the example taken are quite hypothetical and are given solely for purposes of illustration. The basis or "job rate" can be made higher than the estimate if desired, or the division by 2 —the Halsey-Weir system—can be omitted or changed, but in any case the opportunities afforded must be real, otherwise the scheme may not only fail but may recoil and do damage by making the staff discontented.

One possible weakness in the use of a formula such as the above would be an inducement to a foreman to keep workers employed for the purpose of maintaining their numbers even when an insufficient amount of work was available; in this the weakness of the use of the collective principle shews up in the thought that the effect on the total percentage of his partially employed men would be less, because it would be spread over a larger total, than the effect of the reduction of his own percentage would be if his men were discharged. If desired the operation of the formula could be suspended when the difference between the numbers supervised and the standard number was not greater than a stated percentage, as say 10 per cent.

There are few schemes but which have some counterbalancing tendencies, and against this the alertness of the management must provide.

CHAPTER XIV

THE CONTROL OF RATE-FIXING

THE control of rate-fixing is a question around which has centred a considerable amount of controversy, and to-day practice reflects widely divergent views. At one time it was universal, and it is by no means uncommon to-day, for the fixing of job rates to be vested in the hands of the shop foreman. Under the less strenuous conditions which characterized the manufacturing and commercial world prior to the birth of the twentieth century, when contracts were more frequently placed on a cost basis than is the practice to-day, this arrangement may have given results which were not unsatisfactory. The industrial situation, too, was less difficult, and the linking up of the fixing of job rates with supervision may have had definite advantages. But even as both the commercial and the industrial atmospheres have been changed, each becoming more complex, so must manufacturing routine be adjusted to suit the new conditions.

An age of specialization has succeeded an age of generalization, and the need for specialists is felt in every sphere of manufacture. Specialization, as well as affecting works, in the shape of the products handled, must affect all functions of manufacture, the intellectual worker as personified in the staff as well as the manual worker at the machine or bench.

Specialization, however, is not an end in itself, it is but the means by which the end is sought and that end is economical manufacture. A worker is not kept working at one particular operation solely that he may become expert in its performance, but rather that by becoming expert he will be able to perform such operation more quickly and more accurately, and by doing so reduce the cost. This same movement is taking place in every sphere, in fact it is being realized more and more as knowledge grows that life itself is not long enough to allow one man to become expert on many subjects, and the policy of specialization is one of *force majeure* rather than choice.

The whole subject of fixing job rates is closely linked up with that of supervision and workshop control, and if the sum total of the aims underlying the fixing of rates be but the fixing of rates, it may not matter much under what control it is placed, always

assuming the foreman is held responsible in some measure for costs of labour.

It is becoming increasingly plain, however, that the efficiency of the whole is but the reflection of the efficiency of the individual unit, and the efficiency of the unit can be ensured only by an adequate knowledge of its working ; it is equally as important for the efficiency of a workshop as a whole to be known as it is for the efficiency of an individual worker to be made plain. Thus, production estimating, on which job rates ought to be fixed, can be used as one of the bases from which the efficiency of shop management can be judged not merely for the purpose of apportioning blame, but equally to acknowledge meritorious work.

The question to be decided is a twofold one and might be stated thus :—

A. Are production estimating and rate-fixing such functions that their efficiency can be improved by specialization ?

B. If the answer to A be in the affirmative, how can the best measure of efficiency be assured ; under whose control ?

The importance of the work of rate-fixing can hardly be overemphasized. In empowering any man to fix and give rates, whatever his position, authority is being deputed to spend money and, in the spending of that money, to fix, to a great extent, not only the labour cost of the product concerned, but also the standard on which future manufacture shall be carried out, although not necessarily of the same product, a fact to which too little attention is given. There is also the influence on the industrial relationship of manufacturer and worker to be considered, anything in connection with wages being of special import.

The work in all its aspects calls for that knowledge of manufacturing methods and possibilities and also of human nature which is eminently called for by foremanship, and the allocation of the responsibility to foremen is one which can be supported by sound commonsense. Unfortunately, the minutes in a foreman's hour are but the normal sixty, and there are so many duties which appear to fall so logically to the foreman's lot to perform that some, perforce, have to be wholly or partly delegated to assistants, who in turn have other duties which require immediate attention. In fact, it is very largely due to this that, when in the hands of foremen, the fixing of job rates became so largely a reflection of time taken.

It is contended, therefore, that seeing the estimating of rates of production has such an important bearing on costs and efficiency, the work must be carried out by some official who can make it his chief duty. If this cannot be done by a man who has the duties of foremanship to look after, it must be carried out by another, who will be either responsible to or independent of the foreman. There the question of specialization is involved, more particularly if the works be a large one. Because of the nature of the work it is argued that the estimating of rates of production must be a first

duty, and that, therefore, this cannot be linked up with duties of foremanship. Thus, quite independently of any advantages which specialization may be supposed to give, the logical issue is for rate-fixing to be cut adrift from foremanship. Is there any advantage to be gained by the estimator being made responsible to the foreman? If he be so made responsible, then, excepting time can be given to overlook the rates fixed, the estimator himself becomes responsible really to nobody, and that is what commonly happens where such an arrangement is made. This is not to be desired.

From the standpoint of a knowledge of workshop efficiency the argument is definitely against the foreman being made responsible for fixing job rates. When job rates reflect time taken the record of a week's extra pay earnings is but a record of time taken, written another way. The author remembers two works where this practice existed; the earnings in one case never went above 28 per cent. and never below 22 per cent., while in the other case the district rate per hour was hardly ever mentioned amongst the workers; that quoted was almost invariably the recognized hourly rate of piece-work earnings.

With job rates fixed independently of time taken and based on the amount of legitimate work to be done, the extra pay earnings of a shop, whether shewn in time or money, compared to the total hours worked against such rates, can be used to give a really valuable return and one on which the foreman's remarks may be sought; but if this report be required and it is to be treated seriously, it is obvious that the control of rate-fixing must be vested elsewhere than in the person of the foreman.

In a large works, especially where there are several departments carrying out similar processes, the placing of this responsibility becomes of increasing importance. Additional factors are involved which render the control of rate-fixing by individual foremen a matter of considerable risk, and a central independent authority is clearly required. The need for consistency of opportunities for earning extra pay is admitted on all hands; not only is this necessary as between the workers in one shop, but also as between one workshop and another in the same works. This being so, then the control of the fixing of job rates under one chief rate-fixer or estimator is but in the logical sequence of things, and this is becoming the common practice. Other arrangements have been tried and have been proved to be unsatisfactory; in some instances, opportunities for earning extra pay have been so varied, in different departments of the same works, that men have voluntarily given up their work in one department, remaining out of work for a time in the hope of being taken on in some other department where extra pay was more easily earned.

The central control of rate-fixing makes for efficiency in other directions. Not only is the foreman relieved of a duty which has proved at times to be most harassing, but he is enabled, also, to carry out his remaining duties more efficiently; not only so, but he, as

well as the worker, becomes a critic of the job rates given, and this tends to keep the rate-fixer on the alert and to induce care and efficiency. The more important result, however, is that the individual rate-fixer can be brought under efficient specialized supervision. The chief rate-fixer will be able to bring a specialized knowledge to bear on the questions as they arise, and the collection and use of data from the various departments will tend toward raising the standard of the lower to that of the higher, both generally speaking and with individual processes, and this will react to the benefit of the whole works.

From another standpoint, too, there are distinct advantages. Estimating for the purpose of submitting tenders is the practice to-day; with rate-fixing under the control of foremen, the estimating must be done either by the individual departments or by the estimating department itself; in the latter case there is no definite link between the operations assumed as required by the estimating department and those which would be used in the shops, and very considerable differences are often found, consequently, between the estimated and actual costs.

With job rates fixed as a departmental function, the estimating of labour costs can be more efficiently done by such a department than by any other, and the estimated figures can be kept in view when job rates are being fixed during manufacture.

Another desirable feature is secured when the supervision of the work is centralized, and that is that job records also can be centralized and thus can be more suitably kept. The keeping of job records is an important matter, and requires more room than the shop foreman has to spare and more specialized supervision than he can be expected to give.

What should the fixing of job rates involve? What should be the responsibilities of the rate-fixer? The defining of a rate-fixer's duties and responsibilities is fraught with some difficulty. The preserves of the foreman have already been invaded where the bare fixing of the job rates is concerned, but if the greatest use is to be made of the rate-fixer's specialized knowledge, then even as job rates in reflecting time taken fell short of what was possible, so will they fall short if in them is reflected shop practice only, without any kind of review. Even as the completed product is the result of imperfect workmanship at all stages, so are imperfections likely to be traceable in other directions, and it is essential that, so far as is possible, every endeavour should be made to fix a standard of possible performance to measure the efficiency obtained and to point out improvements that appear possible. If this principle be accepted the fixing of job rates will take on another aspect and become constructive as well as routine in character.

Where specialization is not attempted, a fairly general knowledge of the product and of the whole of the manufacture is likely to obtain; where specialization is the aim, general knowledge may, probably, be less, but that knowledge of particular items which will

exist is calculated to be more thorough and complete than would otherwise be the case.

Where the fixing of job rates has been specialized the rate-fixer's approach to the job is from a different angle to that of the foreman. The foreman may think in terms of accurate manufacture, or of finding work for machines which are falling out of work, but, while both of these considerations are most desirable, they do not involve a comparison of cost. The rate-fixer's training, however, puts time of performance and consequent cost first as a consideration, and, as a result, there is always the tendency to eliminate the superfluous, to look for comparisons, for the purpose of improving output and reducing cost. Thus, the foreman's own arrangements would be brought under review, and where these did not appear to be as economical as possible in their results they would be brought before his notice.

Industrially, too, there can be some advantage. When rate-fixing is done by foremen considerable power is put into one man's hands, and some discontent has been caused by the foreman's attitude over job rates with which workers have been dissatisfied. When the responsibility for fixing job rates is that of some person other than the foreman, the worker can look to getting a less biassed opinion of a complaint than where the responsibility is the foreman's own. It may be thought that both foreman and rate-fixer are regarded alike by the worker as being the servants of the manufacturer, and therefore as having like sympathies. There is some reason for this view, but there is no shadow of doubt that a very large number of foremen hold the respect of their men in quite a liberal measure and that the latter do not hesitate to appeal to their foremen as the occasion demands, receiving treatment which goes to confirm their confidence.

All experience goes to shew that from every standpoint the control of rate-fixing is better vested in some authority other than that of the foreman, although this does not imply, in any shape or form, a criticism of or a reflection on the ability of the foremen as a class, any more than any special ability on the part of any other class of official is inferred. The question is one of time, primarily, and in so far that so soon as a " one man works " becomes increased to a " two man works," there must be division of work, so as manufacturing conditions become more complex must there be further divisions of staff duties. With the need for the division recognized, the different duties can be carried out by the various officials concerned, in unison, not in opposition, and each can be of assistance to the other, and, incidentally, what is of more importance, to the firm. Control, however, must be real and, excepting for reference to the works manager, must be absolute, although the frankest and fullest discussion is to be desired and encouraged.

In some works, with the object of ensuring the foreman's agreement with job rates before they are given, all such are submitted to him for his opinion. In principle there is much to be said for

this practice, but it needs to be borne in mind that, excepting the foreman has sufficient spare time in which to consider these, the method is rather in the nature of a trap to foremen in the shape of obtaining their agreement without due consideration being given, and the days of traps and sharp practice are gone. At the same time it is most desirable that an interchange of ideas between foremen and rate-fixers should take place, but any criticism of job rates by foremen or of methods by rate-fixers should be constructive and be supported by reasons and alternative suggestions. In this connection, excepting a foreman has had the rate-fixer's training, he can be at a loss when workers make complaints, and his judgment might quite easily be warped by the knowledge that the time taken had been in excess of that estimated. A little more broad-mindedness on the part of rate-fixers in explaining to foremen how estimates are built up would sometimes avoid a heap of trouble. A case in point may be of interest.

A worker complained to his foreman that a job which he was expected to do in 3 hours could not possibly be done in less than 6 hours, while at the time he was taking 8 hours. The worker was a steady-going fellow, and the foreman came to the conclusion that a real mistake had been made. The rate-fixer sought in vain to convince him otherwise, but without success. After some unpleasantness, the suggestion was made that an estimate should be taken out in accordance with the procedure being followed by the worker, the details to be given by the foreman. This was done and, to the foreman's surprise, after every detail had been allowed for, as he himself thought the job should and could be done, the resultant job rate was less than that about which the complaint had been made. He did not acknowledge himself entirely convinced, being in the unfortunate position of having agreed that the worker's complaint was genuine, but in the course of a few weeks the actual time taken was brought down to less than that estimated.

This is but one of many examples of a similar character which could be given, and is an indication of the need for education amongst an important section of works staff. Production estimating is a new science, barely out of its infancy. Neither the methods used nor the results obtained are yet satisfactory, and the production estimator is far from perfect. The references made to foremen and production estimator are intended neither to be critical of the one nor eulogistic of the other; it is the methods which must be considered, and with a decision made, based on the recognition of all the factors and with a determination to get as near absolute efficiency as possible, one of the first requirements of which is to know the facts, production estimating will become a major influence, and its place as a function outside that of foremanship will not be questioned.

CHAPTER XV

THE RATE-FIXING DEPARTMENT

THE organization of a rate-fixing department is a question which cannot be discussed except in broad principle. Much depends upon the size of the works and of the general lay-out, while the nature of the work done will be an influential factor. The manner in which the fixing of job rates is to be carried out and the part which the department is to play in relation to the remainder of the work's organization are also likely to affect the arrangements made. In spite of all these factors, however, there are certain principles which should be observed, and which ought to predominate over all other considerations, whether of geography or of policy.

Production estimating, which forms the basis of job rates, is so young a science that its possibilities have not yet been adequately appreciated; it may be the work has been done so indifferently that further appreciation has not been justified, but whatever may be the reason there is no blinking the fact that, whether the work has been badly done or not, or whether it is going to be badly done in the future or not, in its doing a firm's money is being spent, and spent in such a manner that its future, as regards cost of production, is being pledged. These facts themselves call for the organization and control of the rate-fixing department to be of the most efficient kind.

Owing, possibly, to the comparative infancy of the work, efficiency is not always sufficiently pursued, and there are departments in large and important works where, provided there is no trouble with workers and the size of their earnings is not abnormally large, no serious attempt is made to control or to check the job rates given. It is but too obvious that this practice is not good, and should be improved upon wherever possible. To obtain a general idea as to what the organization of a rate-fixing department should cover it is necessary to obtain an adequate idea of its functions.

It has been laid down in a previous chapter that the control of rate-fixing should be entirely independent of the shop foremen, and that the best results will probably be obtained when the chief rate-fixer is made directly responsible to the general manager. In so doing, the work of production can be subjected to an independent

test, to a gauge, as it were, the estimated possibilities to be compared with the results as shewn by the costs.

Primarily, the existence of a rate-fixing department is called into being in connection with the fixing of job rates, but so soon as this takes place the department becomes a unit in the general works organization, and is likely to be given other functions beside the fixing of job rates.

Thus it would obviously be unwise as well as uneconomical, where estimating for tenders is concerned, to have two departments dealing with labour estimates, and it follows as a matter of course that this work should be carried out by the same people, who, later on, will have to fix the job rates. When so arranged there is no transference of information with its chances of error, due to copying or to misunderstanding. On the other hand, the members of the rate-fixing staff, by their constant intercourse with the work of production, have the opportunity of keeping up-to-date, whereas, when independent estimating department staffs do this work, there is a tendency always to judge possibilities according to their recollections of that which happened in the days of their own practical experience. No reflection is intended on the ability of estimating department staffs ; they cannot keep up-to-date excepting they be in constant touch with manufacture.

In some works, the planning of operations is done in the rate-fixing department, and there is much to be said for this arrangement. When more than one method of manufacture is possible the choice, in the ordinary way, will lie with that which is more economical, and the decision is one which can be most readily made in the rate-fixing department. Where the methods decided involve the use of special tools, the decision again is largely one of cost, and this can be appropriately estimated in the rate-fixing department. In those instances where special tools are essential for the purpose of manufacture, as with press tools, or where there is any doubt as to the possibilities of projected tools, discussion with the tool design department is always possible, and should be resorted to as frequently as may be necessary.

Again, the question of operation costs is frequently involved. Costing is commonly looked upon as being essentially a function of the accounting department, but, in so far as an operation cost necessitates technical supervision to ensure that each operation is included, and none but the right ones, costing, in this sense, cannot be done reliably by people who have not the necessary technical experience, and the best results are likely to be obtained when, for this work, the cost clerks are under the supervision of the chief rate-fixer.

Another function is that of checking the job rates given, to make sure that same are correct, as compared with estimate, and that no illegal alterations have been made. This is thought by some people to be unnecessary ; a refinement which has no real value but without a check illegal alterations made would rarely be found out, if at all, and each successful attempt at fraud encourages others. The

experience is that such alterations do get made, both to job rates, to quantities to be made, and to numbers "passed" by the inspector as correct. Such a check has a good influence on everybody concerned, tending to keep a high standard of clerical accuracy.

It is sometimes found convenient for the control of the writing of job cards to be brought under the rate-fixing department, although this is not likely to affect the organization and needs no extended reference. When operation costing is done in the rate-fixing department it follows that the job cards will be filed there for purposes of reference, they being useful there, too, in case of queries being raised by workmen as to the accuracy of job rates for operations which are being repeated.

One of the most suitable methods of filing these cards is in trays about 30 inches long carried in covered racks, the top of which, formed as a table, provides good sorting facilities. Sorted into drawing and order number and, if justified by quantities, into operations, reference can readily be made.

For the purpose of operation costing, it needs to be remembered that isolated results are not likely to convey a true idea of the actual cost, and the greater the number of cards included in such cost the more accurate will the figures be likely to be. The error would be just as likely to be up as down, and some discrimination is necessary as to the inclusion, at their face value, of cards for early batches or on which an abnormal amount of scrap is shewn.

Arrangements should be made for noting those instances where the estimated time has been exceeded and, dependent upon the percentage or on the amount of excess, enquiries should be made as to the reasons. It does not follow that an excess means an inefficient or an indolent worker; unavoidable delay or obstructions may have been met with, for which allowance should have been made; the job rate may be too low, actually, or because an unsuitable machine may have been used. Either of these requires investigation, and, while correction in such cases may appear to be uncalled for liberality, its doing is a proof of honesty of purpose and makes it easier for a strong line to be taken with workers who are known to be indolent.

The suitable making and filing of records is one of the most important functions of the department, and requires to be done with the greatest care.

These matters are all referred to at greater lengths under their respective heads. Summarized, the obvious duties of the rate-fixing department are as follows:—

1. To estimate rates of production as bases for job rates.
2. To pass job rates to workers.
3. To provide suitable records of job rates.
4. To check job cards for clerical accuracy and against illegal alterations.
5. To estimate labour costs for tenders.
6. To check performance results and set necessary enquiries on foot.

Other duties which can be efficiently carried out by the rate-fixing department are :—

7. To plan operations.
8. To construct operation costs.
9. To control the writing and issue of job cards.

The organization of the department must be so arranged that each and every one of the functions mentioned entrusted to it can be suitably carried out. To this end, the chief rate-fixer should employ such general assistance as may be necessary to ensure the requisite attention being given, and where any of the duties are delegated he should receive such reports, or should periodically personally investigate, so that he can assure himself that everything is being satisfactorily done. All reports as to errors in job rates, queries arising out of job rates, waiting time, special allowances, and exceeded times should be dealt with by him promptly, with the object of ensuring that the administration of the system generally is such as to justify the confidence of the workers.

To obtain and retain the confidence of the workers in the system in use, and to obtain economical production, is the acid test to which all systems of payment by results will be subjected sooner or later, and it should be the aim of every chief rate-fixer to see that his department is so managed that the workers can rely, without fear, upon getting a square deal. When and where this is the position, firms are to be congratulated, and the future of their system of payment by results and, what is of more importance, of the cost of their future production, in accordance with the possibilities afforded by their plant, can be looked forward to with equanimity.

CHAPTER XVI

THE CHOICE OF STAFF

THE importance of choosing the right men for any staff appointments is being increasingly recognized, and the success or failure of departments is bound up, to a considerable extent, in the efficiency with which they are staffed. While the importance of having the right type of men may be recognized, the general recognition of the need for training is not so clearly in evidence, and there are many instances where staff duties are carried out by men who are purely technical and have had no training whatsoever in the carrying out of the more important duties assigned to them. This has often been the case in connection with the work of fixing job rates, and serious difficulties have resulted.

The general question of the choice, appointment and training of staff cannot be dealt with here, but it ought to be recognized that both the choice and the training of rate-fixing staff are of vital importance if efficiency of output and cost and peaceful conditions in the workshop are to be obtained. There is probably no work in connection with the administration of engineering manufacture which calls for such varied qualities as does the fixing of job rates.

In the first place, the rate-fixer must be a practical workman of at least average ability, able to state how operations should be carried out ; the most suitable machine to use ; the best methods of clamping ; the most efficient tools ; he should have sufficient knowledge of the product to recognize and to be able to specify, if necessary, the class of finish required and possible ; the speeds at which the different metals can be efficiently and economically cut ; and what feed and depth of cut constitutes a fair performance both for the machine to carry and for the job to stand.

Where fitting work is concerned, it is an advantage for the rate-fixer to have a knowledge of machine processes also, if only to enable him to speak with authority as to the degree of accuracy, etc., which can be expected with machine work. While it is advisable for a rate-fixer handling fitting operations to be a competent fitter, this is not so important as is the case with machine work where actual practical experience, only, enables the required knowledge to be

obtained, and, generally speaking, most turners have had some experience with the use of fitters' tools.

In addition to practical experience, a fair education is necessary because of the need for calculation. Many excellent workers have been tried as rate-fixers, and have failed simply because of their inability to calculate. Of course, this is a weakness which is constantly being eliminated by the better standard of education prevailing to-day, but there is much left to be desired in this respect even with young men in their early twenties. In many cases the arithmetical sense seems to be utterly lacking. What is needed is not only the knowledge of arithmetic and the ability to work out simple problems, but the gift also of seeing whether or not the results are approximately correct. The author remembers a case where an item of 72.0 minutes was worked out as 720 minutes. The whole value of the job was 300 minutes, but in spite of its magnitude the arithmetical error was not discovered.

A rate-fixer should also be a keen observer. He is always spending the firm's money, committing them largely as to the cost of their productions, and it is his business to make sure that his spendings are wisely made ; that he does not offer more money than the return is worth ; this is held to cover not only value for money as regards workers' efforts, but also the suitability of the operations themselves. If work is done by methods which are not economical, the rate-fixer should note this and make enquiries, referring the matter to his chief if not satisfied.

In some cases the rate-fixer is apt to be guided in his estimate by what the worker tells him; he should be sufficiently observant, however, to pick out the facts, point out the errors or ignore them. In this connection it should be remembered that it is the worker's business to make the most of an operation, and, in doing so, provided he sticks to facts, he should not be thought to be guilty of unfair dealing ; he is in a position similar to that of a salesman selling his wares.

As well as being observant, the rate-fixer should be determined and, at the same time, tactful. It is difficult to say which is the cause of most trouble, weakness of character or tactlessness. A rate-fixer having ascertained the details of an operation, and made his estimate out accordingly, must be able to stand up against criticism of his work. Workers can be genuinely mistaken and also can be deliberately unfair where the sufficiency of job rates is concerned, and, while the rate-fixer should listen courteously to the complaints made and be prepared to revise his estimate whenever justified, he should also have the strength of will to stand up for his estimate when he is satisfied he is not in error. To do this without causing offence often requires great tact, and the trials of the position are not always sufficiently appreciated ; at the same time a lack of tact makes the difficulties infinitely greater.

In this connection it is well to bear in mind that the rate-fixer is always handling the wages question, than which, it is recognized,

none is more contentious. In his work, all the time, are operating the two opposing interests of the employer and the employee, and talent of a high order can be well used.

Determination and tact are equally required in dealing with the members of the staff, particularly the supervision staff. The rate-fixer's duties, if they are to be efficiently carried out, are at times of a critical character, and the supervision staff do not always welcome criticism even when put in the form of suggestions ; efficiency, however, must always be the aim, and no opportunity should be lost of making improvements with this object in view.

Having specified in some measure what qualities are required to make an efficient rate-fixer, it will be useful to indicate somewhat the lines on which to make a choice. The choice is of importance, apart from the efficiency standpoint, because the training necessary before a man can be trusted to fix job rates is a lengthy one, and if the man chosen should prove to be unsuitable, both time and money will have been lost.

The examination method has never been used in this country as it ought to be, and, consequently, our methods of choosing staff are of the crudest and the most unreliable that could be devised. Where the circumstances are such that no choice exists, there is nothing to do but to make the best of a bad job, but such instances are the exception and not the rule. If a choice is being made from men who have already had experience, the matter is one of test, either written or oral, as to the experience of the candidate and his methods of estimating output. He should be asked to indicate his knowledge of methods by laying out from the drawings of one or more typical parts the firm is manufacturing the operations necessary for manufacture, stating also the tools required. His knowledge of estimating and rate-fixing—his ideas of the value of work—would be indicated by his stating the approximate times in which the various operations should be performed. Seeing a candidate may be nervous at such an interview, opportunities could profitably be afforded him to make out written estimates which might be a more satisfactory test, under the circumstances, than one purely oral.

The testing of the powers of observation of a stranger to the district and the works is not always an easy matter. In the walk or ride from the railway station to the works a candidate may be so preoccupied with the interview before him as to give attention to nothing else ; again, he may be interested in clouds, and thus not see buildings and *vice versa*. During the interview he may be nervous and thus not do himself justice, and it is quite often a fact that intelligence and sensitiveness go together, producing a tendency to apparent nervousness which can be quite deceptive. Excepting some obvious outstanding opportunity discloses itself for making a satisfactory decision, this is a matter for the natural intelligence of the interviewer.

Where it is desired to take men from the works and train them the question becomes one of a different character. Numerous tests can

be imposed which will be useful even to the unsuccessful candidates, should they be told the causes of their failure.

In any case, all applications should be by letter in the applicant's own handwriting, and the construction of same will form an indication as to the education and, also, the ability of the writer to express himself intelligibly. Particulars of the applicant's experience should be given, and the manner in which this is done noted.

Letters often contain evidence of the writer's lack of exercise of the power of observation. An application was once received from an excellent workman, with the name of his firm wrongly given and one of the names incorrectly spelt. That man would probably have been just as careless in spending the firm's money, or as regards giving the men fair rates, as he was in his correspondence. He was not appointed, but was continued as a good workman who had reached his limit.

Where a knowledge of arithmetic is concerned, this is a matter of simple examination or the production of certificates which indicate the standard required has been achieved during recent years. At this period, however, educational opportunities are so good that, in such an examination, a standard higher than that required by the nature of the calculations to be made might with reason and profit be set.

The possession of determination and tact will usually be a question of judgment ; the candidate's foreman will be able to give some information on this point, while a fair idea of these can often be gleaned during conversation, and sometimes, in the case of determination, by a review of the records and of the candidate's previous experience.

While one can hardly put the same questions to men, the results of mental tests with boys and girls are of interest. The author required a number of these for the purpose of checking calculations many of which could be done mentally. Efficiency in staff matters is always as important as with hourly-rated people, and after general personal suitability had been proved one of the tests was to work out, mentally, three simple arithmetical problems, 3 minutes being allowed for each. In some instances not one answer was given, correct or otherwise ; in others, 3 minutes were taken to give an answer at all, and these were sometimes correct, sometimes wrong ; again, several wrong answers were given and none right, while others succeeded in giving the correct answer after several wrong ones had been given. Really satisfactory answers were in the minority of one in three. Some of these were given in 10 seconds ; in a few cases the question was repeated, after which correct answers were given. The choice was made from amongst those who answered correctly or who appeared to be nervous, although the latter were submitted to other tests later. The results obtained from the boys and girls so chosen amply justified the trouble taken and proved the utility of the method.

The need for punctuality, the observance of works regulations,

and the possession of good character are assumed as being attended to in any case.

As an indication of the need to recognize that an apparently nervous man is not necessarily likely to prove a failure, the author would mention an instance where he had recommended a man for an important post, which required tact and determination. This man was interviewed as one of a number of candidates, but in spite of the recommendation made he was likely to have been turned down because he was nervous. The suggestion was made that this apparent nervousness was due to the sensitiveness of intelligence, and was desirable in the case rather than otherwise. The appoint- was made, and in six years the abilities of this individual have enabled him to rise to the chief executive position in the works, leaving behind or displacing less nervous men.

The need for rate-fixers to be trained is possibly of greater importance than is the case with foremen, if comparison be at all possible, although this is not because the duties are more important so much as the fact that every job rate given becomes a standard of cost and of reference. If a novice be allowed to fix rates, as is quite often done, he can hardly avoid making some mistakes, but these will stand as job rates just the same as the work of experienced men ; such rates cannot be labelled as beginners' errors, and must perforce stand. It is this condition which necessitates the satisfactory training and equipment of the rate-fixer.

It is a good practice where the operations are planned in the rate-fixing department for the novice to be given planning to do first. This work broadens his ideas, enabling him to get a more general outlook on the work of manufacture, and cultivates the " how to make " attitude which is so desirable. Following this, the arithmetical formulae should be taught, together with hints as to the handling of speeds, feeds and depths of cut. It will be an advantage if, at first, estimates are taken out for operations which have already been done, so that under the guidance of an experienced rate-fixer the estimate can be compared with the results actually obtained.

In this connection it is useful to have a number of such operations with their respective estimates, the details of which have been proved to be correct ; these, together with the output records for same, would prove to be of real help to a novice. The record of tabulation (see Chapter XXIV.) will be found of great value in this respect.

As progress is shewn, more difficult operations can be chosen for estimating, and the novice may be allowed to make out estimates for new work, these to be submitted to an experienced rate-fixer for his approval and acceptance ; from this stage to working without further tuition is a matter dependent upon the amount of progress made.

Followed out on these lines efficient rate-fixers can be trained from among a firm's own workmen, and this will present opportunities for advancement which will be much appreciated by work-

men generally. Because of the value of this training and experience a number of firms have found it worth while to arrange that all their foremen shall pass through the rate-fixing department as rate-fixers before being appointed as such. The policy is an exceedingly good one and helps in the building up of a well-informed works staff whose outlook will be efficiency, cost as well as production.

CHAPTER XVII

NOTIFYING THE WORKER

WHILE the estimating of correct job rates is a most important matter, these cannot be regarded as fixed until they have been offered to and accepted by the workers concerned, and in the manner in which this is done can lie much of the success of the particular system which may be in use. In some circles it is thought that trouble with payment by results is largely due to the fixing of incorrect job rates and to their subsequent reduction. While there is much truth in this belief, it is not, necessarily, always the case, and there have been many instances when trouble has been experienced even though job rates were right. It must not be forgotten that much of the success of payment by results hinges on goodwill. Taking the mere brutal view, if employers had found it possible to obtain maximum output when using the time system, payment by results would not have been resorted to. Under the time system, authority and the methods used have failed to secure the desired results, and it is clear that, as payment by results is intended to serve as an inducement to greater ouptut by appealing to the workers' liking for large earnings, this object will be achieved not by the fixing of correct job rates only, but by the workers believing that those rates are correct and carry with them reasonable possibilities of a fair reward for the efforts to be put forth.

This view of the position does not always obtain, and the attitude of " take it or leave it " is sometimes adopted, which is bad for a firm financially and for the discipline as well. Instances are known where the job rates fixed have been exceeded for periods of upwards of twelve months, largely because they appeared to the workers to be on the low side. The avoidance of such a situation is much to be desired because, indirectly, the management of the works are acknowledging one of two things: that they do not feel sure their job rates are really correct, or that they are indifferent to what amounts to a deliberate restriction of output. The reasons for the existence of such a position, if analyzed, will often be found to rest on the workers' doubt, as to the possibilities of earning extra pay, to the bad handling of the situation, or to temporary conditions which have rendered the job rates insufficient so long as those con-

ditions obtained. It is not uncommon or unreasonable to find that on new operations, even if they are not unlike others which have been done previously, there is a certain unhandiness felt, which prevents the best results being obtained, while, if the nature of the work be quite new, normal output at first may be absolutely impossible. An example of this may be of interest.

The stitching of leather handles was involved, girls being used for the work. It was estimated that there was 23 minutes' work in each handle, but until the girls had become used to the work and their hands had become "hardened," it was anticipated that the time taken would be nearer 1 hour. The work was urgently required, and it would have been profitable to the firm, seeing that the expense of training was unavoidable, if a temporary allowance had been made in addition to the job rate until a fair measure of efficiency had been reached, so that an inducement towards the best efforts would have been in evidence all the time. The instructions, however, were that the correct job rate was to be given and that no allowances were to be made. The result was the girls believed that the estimated time represented an impossible performance and no attempt was made to produce at the rate laid down.

For upwards of six months this was the case, a number of the girls leaving as a result, until special steps were taken to prove to them that the opportunity for earning extra pay was really present in the job rate. Many similar cases have been known where workers of both sexes have been genuinely sceptical in this respect, but after the basis of the job rates had been gone through with them and the details had been shewn to be reasonably allowed for, then, even though the total still appeared to be insufficient, real attempts to earn extra pay have been made, to be followed with success.

The personal touch has much to recommend it, quite apart from any psychological considerations. In discussing with a worker a job rate which has been estimated, the rate-fixer can assure himself that the estimate is truly in accordance with the facts, and should there be any difference, whether due to a mistake in the estimating or to a fault in the method being used, the same can be rectified at once. This is the more necessary with the machining and fitting of intricate or slender articles, where the possibilities of trouble cannot be foreseen, always, in the close detail necessary for the accurate estimating required where job rates are involved.

Anything like autocracy in this connection is to be shunned, while the more ready the firm's officials shew themselves to explain and to enlighten, the more satisfactory are the results likely to be. For this reason, what apparently, from one standpoint, is one of the most desirable methods of informing workers of the job rates estimated can fail and has failed to give the satisfaction desired.

Where operations are planned and the rates of output are estimated beforehand, the methods, by which the manufacturing departments are notified of the operations so fixed, can be used also to notify the workers as to job rates. Such a means, because of the publicity

given, automatically conveys an impression of permanence of job rates : it certainly tends to make the surreptitious reduction of job rates difficult. Unfortunately, this very appearance of permanence, together with the impersonality of the method, can prove to be an element of weakness ; the appearance of permanence, which might be expected to engender confidence, is looked upon, in some cases, as a kind of autocracy against which it would be useless to appeal. Logically there is no reason for this attitude, but, as with other questions, the basis of consideration must be facts, however illogical these may appear to be. If by explanation such an attitude can be changed, good, but there is little doubt that it is the better plan to arrange that the workers are notified of new job rates by a personal visit of the rate-fixer, and, if publication of same is to be made, that this shall not be done until they have been proved to be acceptable.

At once this causes a difficulty regarding the use of the operation schedule for this purpose, because the earliest possible issue of this is desirable for the information of the shops. The withholding of these until job rates have been proved to be acceptable cannot be considered, while their recall for the purpose of adding the job rates as they are accepted is somewhat undesirable, particularly if the operation schedule is affixed to the drawing, its most useful place. Where repetition work is concerned and operations are likely to be repeated for long periods, the issue of a preliminary schedule without job rates is worthy of consideration, the permanent schedule, with job rates typed in, to be issued at a convenient time afterwards.

So soon as this is possible there will be no need for the skilled estimator to spend time in dealing with job rates for operations which are being repeated. The operations fixed should be numbered, and the quotation of the requisite number should be all that is necessary to indicate both the operation and the appropriate job rate. With job rates published so that workers can see them there is no need for any further individual notification, and, as a job is finished, the extra pay earned can be computed by noting the quantities passed as correct and multiplying the job rate as required.

The time at which a worker should be informed as to the job rate estimated is a matter of some importance, and this, of course, is affected by the methods in use as regards the planning of operations. When this is done beforehand, it is possible for the job rates to be prepared accordingly and for the worker concerned to be dealt with immediately he has commenced his operation. When operations are not predetermined it is obvious that estimating cannot be commenced until the extent of the operation has been decided and the information conveyed to the estimator ; this is done usually through the medium of a job card.

This routine means, however, that, excepting an excessive number of estimators is kept, delays more or less lengthy will take place, the work being proceeded with in the meantime without a job rate.

This is not good in any case, but becomes the more objectionable as the jobs being done occupy a short time, and this shows up in two distinctly opposite directions.

The worker objects to waiting for job rates because, until the rate has been fixed, he does not know whether it is going to be worth his while to do his best or not, and so he works at " daywork " speed until this has been done. He fears to do otherwise, because he thinks the rate-fixer may be watching him for the purpose of seeing what progress is being made, and that good progress will mean a smaller job rate ; conversely, he thinks that slow progress will mean a higher job rate. Excepting where the basis of job rates is estimated time there is probably some justification for the fear, but, in any case, the sooner the job rates are fixed after the commencement of the respective operations, the better the output results are likely to be.

There is an objection, however, to delay in the fixing of job rates from the firm's standpoint, and this is particularly the case when the estimating is inefficiently done. When delay takes place, the worker " goes easy," and, if the job is so near completion before the job rate is fixed that the opportunity for earning extra pay is gone, he not unnaturally feels aggrieved, voices his vexation, and the estimator, feeling himself in the wrong, sometimes tries to keep the peace by giving a higher job rate than is justified by the estimate. There are works where this practice has caused the rate-fixing to become so degenerated that the job rates are fixed, after the work has been completed, at a level which will give earnings of time and a third. Thus, it is possible for payment by results and estimated job rates to be so prostituted as to be no better in their influence than " time and a bit."

This is a state of things which is more common than is usually thought to be the case, more especially when the operations done are in connection with millwrighting, tool repairs, and rectification work. Serious and persistent attention is necessary if such a state of things is to be avoided.

It is useful to observe a rule that, according to the nature of the work and the duration of the operations, workers should be informed of their job rates within one, two or three hours after the operations have been commenced, the period fixed to be in accordance with the class of work and the duration of the operations. In some works job cards in the shops are periodically examined for this purpose, and a report made of all cards on which the job rates had not been filled in.

Superficially, such a method should have good results, but, assuming the individual estimator has a task which should be satisfactorily accomplished inside the time laid down, the inference is that he and his fellows are not trustworthy, and require this policeman type of supervision in order to be kept up to scratch. One of the results is that that man who is the least scrupulous, seeing the card inspector coming, fills the job rates in promiscuously and thus shews a clean

sheet while his more scrupulous and straightforward fellow receives bad reports—so long as he remains straightforward.

In a department which was suitably supervised a better method should be possible, or, rather, a higher code of honour should be encouraged, and this would be to the advantage of the firm and would add to the dignity of the department and its members.

CHAPTER XVIII

JOB RATES FOR APPRENTICES

WHILE provision has been made whereby, under practically all conditions of manufacture, every kind of contingency can be met, in the discussion, all the time, it has been assumed that the abilities of fair average men have been available. Such an assumption is neither incorrect nor unfair, and, where fully-rated men are concerned, no other course should be followed. The position is not the same, however, when juniors are employed, more particularly when they are learning a skilled trade as is the case with apprentice engineers. Then, as ability to produce depends to a considerable degree upon experience, it is obvious that apprentices in lacking experience must be handicapped as regards output, and that, if their best efforts are to be induced, a lower standard of output must be expected than is the case with adults.

The question is one full of difficulty, because of the varying nature and duration of the apprentices' experience and of the degree of skill required in the different classes of work to be handled. Thus, where purely roughing operations are concerned, a short amount of training only is required to enable an apprentice to turn out as much work as a fully-rated man ; on the other hand, there are many operations which are entirely beyond the skill of an apprentice to do at all in his early years. Again, an apprentice may be able to turn out perfect work from a machine while, with a similar amount of experience, the results in fitting work, because there is no mechanical aid to accuracy of shape, as with machine work, may be vastly different.

It will be clear that no single arithmetical formula can cover these varying conditions. At the same time, if the best efforts of apprentices are to be obtained, some form of control or inducement must be used, and, excepting there be some basic idea of the possibilities of output on a given job from an apprentice of known experience, control is likely to be ineffective or to be of an irksome character, prejudicial to the outlook of such boy, while inducement in the shape of job rates could be based on nothing better than an ill-considered guess.

The evils of this latter would be restricted where it was possible

to give apprentices "apprentices'" jobs always, but a division of work on these lines is exceedingly difficult to make in some industries and, when made, cannot always be given effect to. In those cases where the nature of the work is such that men and apprentices must work together, as, for example, with some assembly operations, or, when more than one shift is being worked, and apprentices work one shift and men the other, some method of dealing with the question is a necessity, and in the interests of the apprentices themselves, and in equity to the men, some satisfactory understanding is essential.

Theoretically, it will be plain that if five years are required to convert a raw youth into an efficient mechanic, the efficiency of such a youth will vary at different periods from nothing to 100 per cent. The first item to be decided is what can be reasonably expected from a youth during his first year; some preliminary training in the use of tools and in the movements of machines should be given before an apprentice is put to work on any system of payment by results. This ability expectation has been commonly accepted as being 50 per cent. of the output of a man. The influence of class of work in this connection will be dealt with later. If, for purposes of illustration, 50 per cent. can be accepted as representing reasonable expectation, it is not difficult to arrive at expectation figures for other years, and these could, quite fairly, be as follows:—

1st year apprentices - - -	50 per cent.
2nd " " - - -	60 " "
3rd " " - - -	70 " "
4th " " - - -	80 " "
5th " " - - -	90 " "
Man's output - - - -	100 " "

To give effect to these figures, however, some form of adjustment to job rates is necessary, and this will have to be chosen from among the three methods given below.

1. To estimate the basis for job rates on the lower output rate expected from apprentices as shewn.

2. To reduce the time spent on a job by a percentage appropriate to the apprentice's experience and to count this reduced time as the time taken.

3. To increase the job rate.

There is a decided objection to any interference with the basis of estimating, because such is not only illogical, but is apt to be confusing as well. It is a sound principle to estimate on one basis all the time, *i.e.* on the abilities of an average man. An estimate then means one thing, always, all the time, and then there can be no confusion as to whether the abilities of a man or an apprentice of one or other year of experience are reflected therein. Quite apart from the fact that there could be no less than six estimates for the same operation, it is bad policy to estimate on any basis other than that of actual performance. To take an illustration, a machine will

not run the slower because an apprentice puts the starting lever over; the cutting speed used, in the ordinary way, will be the same; the difference will not be in the rate at which the machine is run, but in the less skilful handling of the same. This lack of skill is felt at every handling stage of the operation, and can be dealt with by other and better means than altering the basis of job rates.

The method adopted must be to count less time in a given proportion than that actually taken, or to increase the job rate in an appropriate manner, and these are the methods commonly adopted.

Using the percentages quoted to illustrate the working of the two methods, the time counted for the different years of apprenticeship would be equal to the appropriate percentages of the time taken. Thus, 100 hours taken would be counted against the job rate as follows:—

	Hours.	
	Taken.	Counted.
1st year apprentice - -	100	50
2nd ,, ,, - -	100	60
3rd ,, ,, - -	100	70
4th ,, ,, - -	100	80
5th ,, ,, - -	100	90

Under this method, if a 2nd year apprentice took 100 hours to perform an operation for which the job rate was 100 hours, then, although actually no time would have been saved, the time counted for purposes of calculating extra pay would be 60 hours, which, under any of the systems of payment by results in use, would carry with it extra pay.

If the practice were to increase the job rate, the procedure would be to express the percentage quoted as a decimal; 80 per cent., for example, would become .8 and the job rate would have to be divided by that figure, thus:—

Man's job rate - - - - -	100 hours.
Divisory expectation factor - -	.8
4th year apprentice's job rate -	125 hours.

The job rate for a 4th year apprentice on this basis will be seen to be 25 per cent. more than that of a man. The results are the same under both methods, provided that the percentage arrived at under the "time counted" method is paid on the time taken. Thus, under the "time counted" method, a job which it was estimated would take a man 60 hours to perform, would, on the basis of the expectation factor used, take a 4th year apprentice 75 hours to complete, and 80 per cent. of this time would be 60 hours. With a man's job rate of 100 hours this would mean 40 hours saved, and this under the

Halsey-Weir system would signify 20 hours extra pay or 33·3 per cent. 20 hours extra pay, however, on 75 hours taken would be but 26.6 per cent., less than that percentage actually earned. 33·3 per cent. of 75 hours, the time taken, would be 25 hours ; this amount would be correct. For the two methods discussed, the hours likely to be taken, on the basis of the factors laid down, for a job estimated to take 60 hours, with a job rate of 100 hours, have been worked out. The "hours taken" are arrived at by dividing the hours estimated by the expectation factor, thus :—

$$\text{Hours taken by 2nd year apprentice} = \frac{60}{.6} = 100 \text{ hours.}$$

Year of Apprenticeship.	Hours Taken.	Method Used.							
		Time Counted.				New Job Rate Hours.	Increased Job Rate.		
		Hours Counted.	Hours Saved.	Percentage.			Hours Saved.	Percentage.	
				Saved.	Extra Pay.			Saved.	Extra Pay.
1st	120.0	60	40	40	33·3	200.0	80.0	40	33·3
2nd	100.0	60	40	40	3·3	166.6	66.6	40	33·3
3rd	85.7	60	40	40	33·3	142.8	57·1	40	33·3
4th	75.0	60	40	40	33·3	125.0	50.0	40	33·3
5th	66.6	60	40	40	33·3	111.1	44·5	40	33·3

To what extent one method has advantages over the other is difficult to say. Calculation is needed to obtain either the increased job rate or the time to be counted, while, with the latter method, the percentage needs to be calculated, in addition, before the extra pay due to an apprentice can be ascertained. The calculations necessary to arrive at the increased job rate will be made by a highly-paid rate-fixer, perhaps, while those incidental to the time counted method will be made by clerical people at lower salaries. Against this latter, the greater the number of calculations required the more are the chances of error, and, of course, the more difficult will it be for the apprentices themselves to follow.

On the other hand, interference with job rates is avoided under the time counted method, the one job rate standing for all grades, a matter of some importance. At the same time, however, when the factors for the modifications to job rates required for the apprentices of different years are published in the works, as they should be, the objection to such modification in this connection largely vanishes.

The work entailed by the use of the two methods is shewn below, the particulars in each case being the same.

Estimate, 60 hours. Job Rate, 100 hours.

Time assumed as taken by second year apprentices = 96 hours.

TIME COUNTED METHOD.

Time taken - - - -		$=96$ hours.
Time counted - - - -	$96 \times .6$	$=57.6$ hours.
Time saved - - - -	$100 - 57.6$	$=42.4$ hours.
Extra pay due if man had done job	$\frac{42.4}{2}$	$=21.2$ hours.
Percentage extra pay - -	$\frac{21.2}{57.6}$	$=36.8$ %.
Extra pay due to apprentice	$=\frac{96 \times 36.8}{100}$	$=35.3$ hours.

INCREASED JOB RATE METHOD.

Estimate for apprentice -	$= \frac{60}{.6}$	$=100$ hours.
Job rate for apprentice -	$=100+66.6$	$=166.6$ hours.
Time taken - - -		$=96$ hours.
Time saved - - -	$=166.6-96$	$=70.6$ hours.
Extra pay - - -	$= \frac{70.6}{2}$	$=35.3$ hours.

The two methods can be applied both to the Rowan and to the Halsey-Weir systems. From the standpoint of ease of working the increased job rate method will be seen to be the simpler.

The position is somewhat different with the modified Taylor system, owing to the fact that the job rate is given differently, and, also, that the amount of extra pay due is not arrived at by the use of the one formula at every stage of time taken. The " time counted " method can be applied if desired, but, as with other systems, the amount of calculation required would be greater. The procedure would be as follows :—

$$\text{Time counted} = \text{time taken} \times \text{appropriate factor}.$$

If the time counted is not greater than the estimated time the full amount of extra pay will be due, but this must be increased by submission to the following formula :—

$$\text{Extra pay} = \frac{\text{normal amount}}{\text{appropriate factor}}.$$

Then, with the estimated time of 60 hours, 20 hours extra pay, and 96 hours taken by a 2nd year apprentice, the extra pay calculations would be worked out thus :—

$$\text{Time counted} = 96 \times .6 = 57.6 \text{ hours}.$$

The time counted not being greater than that estimated—60 hours —the full amount of extra pay would be due.

$$\text{Apprentice's extra pay} = \frac{20}{.6} = 33.3 \text{ hours}.$$

Should 140 hours be taken, the time counted would be 84 hours, and this being in excess of the estimated time plus the extra pay amount, no extra pay would be due.

It would be simpler to increase the estimated time on the same lines as used when the increased job rate was concerned. Thus:—

Apprentice's estimate - - $= \frac{60}{.6} = 100$ hours.

Apprentice's extra pay - - $= \frac{100}{3} = 33.3$ hours.

Time taken - - - - $= 96$ hours.

Extra pay - - - - $= 33.3$ hours.

Should 120 hours be taken, the extra pay calculations would be as follows:—

Extra pay - - $(100 + 33.3) - 120 = 13.3$ hours.

There still remains the piece-work or plain premium system to be considered, for which the treatment necessary is somewhat different. The job rates under this system are usually given in terms of money, and the question of adjustment is one of reduction rather than of an increase in job rate. Under the sharing systems, the extra pay shewn as due is paid in hours at the respective time rates; when the job rates are expressed in terms of money, the time estimated at an accepted general figure, such as the district time rate of wages, is embodied in the job rate and the position is changed, because of the influence of the hourly time rate on the job rate. Thus, if the time rate of a 1st year apprentice were 2 pence per hour and that of a fully-rated man were 1/- per hour, the basis value of the man's job rate would be 6 times that of the apprentice, whereas the recognized increase required is double only. The appropriate adjustment can be made, however, by working from the estimated time rather than from the job rate, and estimated time is really the logical factor to deal with, because it remains constant. Thus, if 33.3 per cent. earnings are to be provided for, as with men, the procedure will be the same as followed with the increased job rate, excepting the estimated time rather than the job rate will be dealt with. The formula is as follows:—

$$\text{Apprentice's estimated time} = \frac{\text{man's estimated time}}{\text{expectation factor}}.$$

If the estimated time were 12 hours and the apprentice were in his 2nd year, then:

$$\text{2nd year apprentice's estimated time} = \frac{12}{.6} = 20 \text{ hours}$$

and the job rate = (hours × time rate) + 33.3 per cent.

On the basis of the figures previously used on page 180, piece-work job rates for apprentices for the time rates quoted would be as shewn in the appended table.

PLAIN PREMIUM SYSTEM.

Job Rates for Apprentices.

Man's Estimated Time—60 minutes. Man's Time Rate—1/-.

Man's Job Rate—1/3.

Year of Apprenticeship.	Hourly Time Rate in Pence.	Estimated Time in Minutes.	Job Rate in Pence.	Percentage of Man's Job Rate.
1st - -	2.0	120	5.33	35.5
2nd - -	2.5	100	5.55	37.0
3rd - -	3.0	85.7	5.71	38.0
4th - -	3.5	75.0	5.83	38.9
5th - -	4.0	66.6	5.93	39.5

Using the time rates shewn, there is not much difference between the job rates for apprentices in their various years, although, if the range of the time rates were increased, these differences would become greater; similarly, if the range were reduced, they may disappear or be reversed. Where the job rates for the different years are so near as in the instances given, it is worthy of consideration as to whether one rate of reduction cannot be used for all apprentices in this respect. The variations from the theoretically correct job rates would be comparatively small and the handling of the job rates would be very much simplified. If this were done the conversion of a man's job rate into one for an apprentice would necessitate the multiplication of such rates by a factor, in this case, say, .4. Nothing could be simpler. Of course, where, for different trades, the time rates for men varied, different factors would become necessary.

In this connection, it is a matter of interest that the practice of giving apprentices a definite portion of a man's job rate in this way is the simplest and the most readily understood of any of the methods in use, being decidedly more easily applied than any of the methods necessary where the sharing systems are concerned, and also, that it is associated with the oldest system of payment by results in use—the piece-work system and, in its modified form, the plain premium system. Thus, apprentices of any year may work with each other without further adjustment of job rate being required, although the extra pay earned would need to be split up in proportion with the time wages earned rather than in accordance with the time taken by each.

So far the matter has been dealt with from the standpoint of apprentices working alone. It is not always possible, however, for apprentices to be kept working alone, nor is it, necessarily, always desirable; in fact, there is much to be gained by apprentices being put to work with fully-rated men. In so doing, they are likely to obtain assistance of a very useful character in seeing, at first hand, the methods adopted by the more skilled workers. To encourage

this as a practice, it is doubly important that job rates should be so adjusted that men will not be likely to suffer a reduction in their earnings, as a result of the smaller output which is likely to accompany the lesser experience of the apprentices. The arrangement should be such that the fully-rated man will be likely to be better off when working with an apprentice than when working alone; when this is assured, men are encouraged to welcome the association with apprentices, and this is calculated to be to the mutual advantage of all concerned.

The methods discussed under which job rates are increased, or the time taken by apprentices is reduced in accordance with the year of the apprentice, enable this provision to be made. Where the "time counted" method is adopted, the procedure is precisely the same, once the time has been "counted," as when two men are working together. Thus, if, with a job for which a job rate of 100 hours had been allowed, a man and a 1st year apprentice had taken 40 hours each, or 80 hours in all, the extra pay calculations would be as follows:—

Man's hours - - 40.	Hours counted - - -	40
Apprentice's hours 40.	,, ,, - - -	20
Total hours worked 80.	,, ,, - - -	60
Hours saved - - - - - - - -		40
Extra pay hours due on basis of man's work - -		20
Percentage extra pay due - - - - - -		33.3
Extra pay hours: man	40 × 33.3 % - -	13.3
,, ,, ,, apprentice	40 × 33.3 % - -	13.3

As when apprentices are working alone, the percentage of extra pay shewn as due must be paid on the basis of the time taken, not on the time counted, otherwise the apprentice will be paid less than the amount earned.

In the case of unequal times being worked by men and apprentices, it becomes necessary to deal with proportions; thus, if the man's time were 20 hours and that of the 1st year apprentice were 80 hours, this would be equivalent to 1 man and 4 apprentices, and the divisory factor would be: man 1, plus 4 apprentices at .5 each. This latter being 2, the factor would be 3. Then the calculation would be as follows:

Man's hours - - 20.	Hours counted - - -	20
Apprentice's hours 80.	,, ,, - - -	40
Total hours worked 100.	,, ,, - - -	60
Hours saved - - - - - - - -		40
Extra pay hours - - - - - - -		20
Percentage extra pay - - - - - -		33.3 %
Extra pay per person or proportion	20 × 33.3 % =	6.6 hours.
Extra pay:		
man —20 hours work—1 proportion -	-	6.6 hours.
apprentice—80 hours work—4 proportions	-	26.6 hours.

When the job rate is increased, the procedure is similar to that followed when the apprentice is working alone, except the man's time is given a value of 1, this value being added to the factor appropriate to the year of apprenticeship as .5 or .8, as the case may be. The reason for this will be obvious, but an example will make the matter quite clear. Thus a job rate for a man which was 100 hours would need to be doubled for a first year apprentice. For a man and an apprentice working together, the combined job rate will be between 100 hours and 200 hours, and the smaller the proportion of time the man spent the nearer would the job rate approach 200 hours.

Taking for purposes of illustration that equal time is worked, the factor would be made up thus:

$$\text{Man} = 1. \quad \text{Apprentice} = .5. \quad \text{Factor} = 1.5.$$

The adjusted job rate would be obtained as follows:

$$\text{Adjusted job rate} = \frac{\text{man's job rate}}{\text{factor}}.$$

A 100 hour job rate would become ($100 \div 1.5$) 66.6 hours each for the man and the apprentice, or 133.3 hours in all. If there were one man, one 5th year apprentice and one 2nd year apprentice working equal time on the same job,

$$\text{the factor would be } 1 + .9 + .6 = 2.5 \text{ and}$$

the job rate would be ($100 \div 2.5$) 40 hours each person, or a total of 120 hours.

With a combination of various year apprentices and men whose hours varied, it is necessary to divide the hours worked so that a common basis is arrived at. Thus, if 20 hours are worked by the man and 15 hours by the apprentice, these hours divided by a common factor of 5 will give the equivalent of 4 men to 3 apprentices. The working out of the job rates for a combination of apprentices would take the following form:

	Hours.	Common Factor.	Efficiency Factor × Number of Proportions.	Divisory Factor.
Man - - - - -	20		1 × 4	4.0
5th year apprentice -	10		.9 × 2	1.8
4th ,, ,, - -	15	5	.8 × 3	2.4
3rd ,, ,, - -	25		.7 × 5	3.5
2nd ,, ,, - -	10		.6 × 2	1.2
	Total hours, 80.		Proportions, 16.	Total Divisory Factor, 12.9.

The job rate would be $100 \div 12.9 = 7.75$ hours for each of the 16 proportions, and these would be allotted as shewn :

Man - - - - - - - -	- $7.75 \times 4 = 31.0$	hours.
5th year apprentice - - - -	- $7.75 \times 2 = 15.5$	,,
4th ,, ,, - - - -	- $7.75 \times 3 = 23.25$	,,
3rd ,, ,, - - - -	- $7.75 \times 5 = 38.75$	,,
2nd ,, ,, - - - -	- $7.75 \times 2 = 15.5$	,,
Total Job Rate	$= 124.00$	,,

It will be seen that this method is quite elastic and can be adapted to any combination of apprentices, men and apprentices, or hours taken.

The procedure under the Taylor (Modified) System is similar. The estimated time and also the extra pay amounts need to be increased in accordance with the appropriate factor. Then

$$\text{the increased estimate} = \frac{\text{man's estimate}}{\text{factor}},$$

and the estimated time of 60 hours for a man, carrying extra pay of 20 hours, would be increased as shewn below, when a man and a 2nd year apprentice had worked equal time on the job.

Factor $= 1.6$

Increased estimate $= \frac{60}{1.6} = 37\frac{1}{2}$ hours each, man and apprentice, or 75 hours in all.

The appropriate amount of extra pay can be obtained in two different ways.

1. Extra pay $= \frac{\text{increased estimate}}{3}$.

2. Extra pay $= \frac{\text{man's extra pay}}{\text{factor}}$.

Thus for the job in question :

1. Extra pay $= \frac{37\frac{1}{2}}{3} = 12\frac{1}{2}$ hours each, man and apprentice.

2. Extra pay $= \frac{20}{1.6} = 12\frac{1}{2}$ hours each, man and apprentice.

For different year apprentices and proportions of time taken, the procedure will be obvious.

Where the practice of a rate-fixing department in dealing with job rates is to quote the estimate on the counterfoil of the job card as well as the job rate on the card itself (Chapter XXII), it may be more convenient to modify the estimate rather than the job rate, adding the usual percentage to form the job rate afterwards. On the other hand these calculations need not be made by a rate-fixer, and when they are left for the timekeeper to work out this point loses any value it may otherwise have. All the same, if only to guard against illegal alterations, the job cards should not be given

back to the workers once the adjustments have been made, although it is important that arrangements should be made whereby those concerned shall be notified of the particulars of such adjustments.

In some works considerable stress is laid upon the necessity for all such calculations as these to be based on the estimated time rather than on the job rate. There are advantages to be gained when straight working is concerned but, seeing that in the circumstances under consideration the calculations are not made until after the work has been completed, the observance of such a rule appears to have but little value. The rate-fixer will have observed it in quoting the man's job rate on the job card, because obviously this is the only thing to do until the proportions of time taken are known.

It is convenient for costing and also for checking purposes for the apportionment of job rates in these circumstances to be shewn for each person. Thus, as shewn in the example in page 186, the job rate would be written down as apportioned.

Man - - - - -	31 hours.
5th year apprentice - -	$15\frac{1}{2}$ hours.

When men work with apprentices under the piece-work system, the procedure is somewhat similar, but instead of the job rate being altered, the estimated time should be dealt with as indicated in the cases of apprentices working alone, and the modified job rate be given as so much per man and so much per apprentice. This is necessary because of the influence of the time rates. Then, if the estimated time on which the job rate was based were 60 hours, and a man and a 1st year apprentice worked 40 hours each or 80 hours in all, the adjusted estimate would be ($60 \div 1.5$) 40 hours for the man and 40 hours for the apprentice, and the job rate would be (hours + $\frac{1}{3}$) × time rate, or hours × (time rate + $\frac{1}{3}$) or other amount as may be decided upon. By this method, as with the sharing systems, any combination can be covered and the working out of the extra pay will be accurately provided for.

So far the methods in common use have been dealt with from a theoretical point of view rather than from the practical one. Under both methods, excepting in those cases where the output is practically the same as the efficiencies estimated, the results can be at variance with the facts. This is due, not so much to the methods used, as to the difference of the output obtained from that expected, the cause being, quite often, the difference in the class of work being done rather than the expectation rating. If, for purposes of illustration, a roughing operation be considered, the material should be removed as quickly by a machine when an apprentice was watching it as when a man was so doing. If the 50 per cent. expectation standard were maintained in the job rates, but a man's output were reached, then, under the Halsey-Weir system, an apprentice working alone would have earned extra pay equal to 116.6 per cent. If a man were working with an apprentice

on such a job, then his earnings would also be increased, while those of the apprentice would be reduced.

For example, if the estimated time for a batch of articles be 1 hour each and they be done at that rate by

A. a man,
B. a 1st year apprentice,
C. a man and a 1st year apprentice,

the resultant job rates, extra pay hours and costs would be as shewn below, the man's time rate being taken as 1 shilling per hour and the apprentice's at 2 pence.

	Job Rate.	Hours.				Cost.	Hourly Earnings Pence.
		Taken.	Saved.	Extra Pay.	Total.		
Man - - -	100	60	40	20	80	80/-	16
Apprentice, 1st year	200	60	140	70	130	21/8	4.33
Man and - -	133.3	30	73.3	18.3	48.3	56/4½	19.3
1st year Apprentice		30		18.3	48.3		3.2

Man's extra pay working alone - - - - - - 33.3%
" " " " with apprentice - - - 61.0%
Apprentice's extra pay working alone - - - - - 116.6%
" " " " with man - - - 61.0%
Cost of 2 batches done separately 1 by man 1 by apprentice - - - - - - - - - - 101/8
Cost of 2 batches done jointly by man and apprentice - 112/9

The importance of this increase in average cost will be appreciated. It is a fact, recognized in most works, that the formulae for dealing with the adjustment of job rates when men and apprentices are working together are at fault, somehow, but, generally, the reason has not been discovered, and in some instances the practice has been dropped as far as possible. Instances have been known where protests have been made by men because they have not been allowed to work with apprentices; when working alone, the men claimed they could not make as much extra pay as when working with apprentices. The significance of this will be made plain by the above figures, more particularly when it is realized that the man is paid the whole of the difference between the cost of batches done separately and done jointly as well as rather more than 25 per cent. of the apprentice's extra pay.

This goes to point out that there is a screw loose somewhere, and when, as can be seen from the reference above that, because of association with an apprentice, for the same amount of work done in the same time, a man's extra pay is raised from 33.3 per cent. to 61 per cent. while that of the apprentice is reduced from 116.6 per cent. to the same figure, it will be appreciated there is a fault existing. This feature is the more pronounced as the apprentice's hours exceed

those of the man, as will be seen from the following table, worked out on the Halsey-Weir system :

TABLE SHEWING EXTRA PAY DUE FOR VARYING PROPORTIONS OF TIME TAKEN.

MAN AND 1ST YEAR APPRENTICE WORKING TOGETHER.

Job Rough.				Output Equal.					
Hours Taken.		Ratio.	Divisor.	Job Rate.		Extra Pay Hours.		Man's. %	Apprentices %
Man.	Apprentice.			Men.	Apprentice.	Man.	Apprentice.		
60	—	—	—	100	—	20	—	33·3	—
50	10	5 to 1	5·5	90.9	18.18	20.45	4.09	40.9	40.9
40	20	2 to 1	2.5	80.0	40.0	20.0	10.0	50.0	50.0
30	30	1 to 1	1.5	66.6	66.6	18.3	18.3	61.0	61.0
20	40	1 to 2	2.0	50.0	100.0	15.0	30.0	75·0	75·0
10	50	1 to 5	3·5	28.57	142.85	9.28	46.42	92.8	92.8
—	60	0 to 1	·5	—	200.0	—	70.0	—	116.6

The solution undoubtedly lies along the lines of using different expectation factors for different classes of work or in keeping apprentices' work quite independent of that of men. Where roughing is concerned, and that is where many of the discrepancies become apparent, this latter should be fairly simple. Where assembly operations are concerned it is a common practice to put an apprentice to work with a fitter to do quite easy jobs and to act as a general assistant to him. The rule under discussion is often applied under those conditions, with the result shewn. It is obvious that the better method would be to estimate for the fitter's work and the apprentice's work separately and to give separate job rates, but that would leave a good deal of the apprentice's time unaccounted for, and this would perhaps be idled as much " assistant's " time is, or be used to help the fitter without being booked. In the latter case this would be likely, eventually, to be claimed as a right.

The subject is one which presents many difficulties. Some compromise is unavoidable and the aim should be that the compromise effected will be to the benefit of the apprentice from the standpoint of experience ; that it will, at least, not penalize the man and will not be unduly expensive. In some respects the latter consideration is the least important.

The relative importance of class of work and experience of apprentices being appreciated, the inadvisability of attempting to lay down any hard-and-fast rules for apprentices' ability values will be obvious ; at the same time, the folly of using a method which is bound to shew a greater reward for rough work than

for more skilled work will be equally obvious, and, for this reason, if for no other, a correction to present practice is necessary. The following is given as a pointer only, it being advisable to split operations into roughing and finishing so far as is possible without calling for additional settings.

OUTPUT EXPECTATION FROM APPRENTICES.

DIFFERENT CLASSES OF WORK.

	Efficiency Expectation.	
	Rough Work.	Finished Work.
1st year apprentice -	75 %	50 %
2nd ,, ,, -	80 %	60 %
3rd ,, ,, -	85 %	70 %
4th ,, ,, -	90 %	80 %
5th ,, ,, -	95 %	90 %

There is the question of the amount of extra pay which should be provided for with apprentices. In pre-war days, it was not uncommon for this amount to be described, loosely, it is true, as double time; that is, the adjustment to "time counted" or to job rates was said to be such that it should be possible for the extra pay earned to equal the time wages. Analyzed, however, the position will be found to be somewhat different. If the job rate fixed for a man be doubled and an apprentice be successful in turning out as much work as a man was supposed to be capable of, then "double time" would have been secured. If, on the contrary, his output was in accordance with that estimated as possible, for his experience, the apprentice would have been successful in earning time and a quarter only, or at the same rate as provided for men.

Thus, theoretically, the provision made for extra pay was for time and a quarter, but, because of the provision of one output expectation factor for all classes of work, rough work provided better opportunities for earning additional wages than did that which was more difficult; and the class of work given to apprentices, being commonly of a rough or easy type, made double wages possible.

This point is of importance, because the influence of the one factor for all classes of work tends to encourage a desire in apprentices to seek rough work for the purpose of earning higher wages. If the more correct view be taken that apprentices are not allowed to seek their own work, the tendency of this unwise arrangement is to cause dissatisfaction, because in doing the more difficult work apprentices cannot earn the same high rates of wages.

Apprentices' wage rates have been increased as a result of the Great War and a somewhat closer check is necessary now than formerly, but whatever may be the amount decided upon as the

basis of apprentices' extra pay, it is desirable that the real facts should be appreciated and that any decisions which may be made shall carry with them inducement to the apprentice not only to do a maximum amount of work but a maximum amount of the most skilled work. Equity for the full-rated man should be provided for and, also, economy in wages expenditure for the firm, it being necessary to bear in mind that the lower wage rates paid to apprentices are counterbalanced, to some extent, by the increased oncosts per unit of production, in that proportion by which the time taken by apprentices exceeds that of the fully-rated men. This factor makes it necessary for careful discrimination to be used in the choice of work to be given to apprentices ; where the work allotted is so difficult that output falls as low as suggested by the efficiency expectation factors mentioned, and the oncosts are on the heavy side, apprentices' labour becomes more expensive than that of fully-rated men.

Thus if oncosts be 1/- per hour and a job be considered which can be done by a man who is paid 1/- per hour in 1 hour, and by a 2nd year apprentice at 2½ pence per hour in 1.66 hours, the resultant costs compare as follows :

Man -	- 1	hour's time wages	at 1/-	plus 1/-	oncosts	= 2/-
Apprentice	- 1.66	,, ,, ,,	at 2½d.	,, 1/8	,,	= 2/0⅛

In the case of a 1st year apprentice, at the output expectation figure used, the excess would be at the rate of 4 pence per hour when the time rate was 2 pence. When the oncosts are higher than those mentioned, actually or proportionally, the excess will be greater. These considerations, alone, render it necessary that job rates for apprentices should be treated as having an important influence on cost if only because of their effect on output and oncosts.

CHAPTER XIX

JOB RATE RECORDS

THE keeping of records of the job rates given is one of real importance, and calls for more attention than is ordinarily given. It is a common experience to find that the filing arrangements for estimating, cost, and correspondence departments are of a most complete and efficient character, while those in connection with the records of job rates are elementary, incomplete and difficult to check. Records are required not only as to the amount of time or money involved; these are but a portion of the job rates, the amount of work allowed for, and the attendant conditious must also be recorded. Job rates are given for the carrying out of certain specified operations, and an adequate record of these is essential, so that when any reference is made, whether for purposes of estimate or of verification, recognition of the operation and its extent, and of the appropriate job rate, will be possible without difficulty or doubt.

While it is not wise to live in the past, useful lessons can often be learned from old practices. If one examines the job rates made when such were fixed and recorded by foremen it will be usually found that the bare job rate figures were recorded accurately, but that the detail as to the amount of work covered by such job rates, and the conditions obtaining, were so meagrely given, if at all, that none but the foreman and the worker, to whom the job rates were given, could be expected to know what the real job rate was, that is, the actual amount of work and remuneration combined. As far as that particular foreman was concerned there was nothing lacking; he knew and no one else wanted to, while in the event of a workman raising an awkward query, the foreman's prerogative of discharge was a useful factor.

Continuity of records, however, is essential to a firm's well-being, and the fact that records of job rates, owing to their incompleteness, have required interpretation has caused much trouble and has cost not a little money. A change of foreman meant the upsetting of records, in fact cases are not unknown where these, being made in books provided by foremen themselves, have been taken away with them leaving no record at all. The author

remembers many thousands of "piece-work notes" being looked up in one large works for the purpose of verifying particulars of operations and job rates, and neither amongst them nor in the records themselves could any operation be traced with certainty, excepting in those cases where there was no choice of process and but one operation of a kind.

An actual example may be cited. Turbine casings were bored in two operations; one, entirely roughing, the second, covering all finishing, but including also the roughing of certain portions not done in the previous operation. The operations were known as "rough bore" and "finish bore" respectively. Certain portions of the work could be done in either operation, and, without making reference to the rate-fixer, the whole of the roughing was put into the first operation, which was a variation of previous practice. The description of the operation and the job rates was left as before. In the meantime, new men had been put on to each operation, and, under the new conditions, had been running for some months when the man who had formerly done the first operation was put back to do this. He at once asked for an increase of job rate on the grounds that his operation had been increased. The man was justified in his request, and this should have been given by adjusting the second operation in accordance with the amount of work by which it had been reduced. The man on the second operation, however, had never performed it when the roughing portion of the work was included and claimed there was no ground for reduction. The looseness cost the firm ten shillings per case extra.

With job rates fixed by estimators, however, new conditions are introduced; the estimator who takes over this part of the work has not the foreman's authority to discharge, and on matters which may be in doubt the worker's tongue is loosed, and, although the job rates may actually be identical with those previously given, a different attitude becomes apparent, the old records begin to cause trouble and the need for precision is felt. After all, there is nothing wrong in this. From every standpoint precise knowledge as to the time value of operations is necessary, not only for purposes of payment by results but, also, for costing and for tendering purposes.

There are large firms in this country to-day to whom the taking out of an actual cost, where a large number of operations on one piece is involved, is a matter of real difficulty, owing to the meagreness of the description of operations and the uncertainty as to what is really meant. It is not practicable to lay down hard-and-fast rules as to what steps should be taken in this respect, owing to the wide variations in conditions and requirements, but there can be no doubt that there is a real and great advantage to be gained when operations are planned, recorded, and followed in the workshops. Haphazard methods are not satisfactory, and it is but logical, and in the interests of economy, that decisions as to methods of manufacture and the extent of operations should be recorded and

observed in future manufacture. By so doing, one of the fundamental requirements for job rates is placed on a sound basis.

Whether operations are planned in this manner or not, there are certain items of information which are necessary. The need for details of operations being given has been made plain, but the question calls for elaboration. In some cases, the use of alternative forms of material is possible, as with bar material, forgings or stampings, without the order or the description of operations being affected, although a different job rate may be required in each case. Instances are common where job rates have been given for machining from the plain bar, and, owing to the lack of information as to the form of the material used, have been repeated when forgings or stampings have been provided, whereas new job rates should have been given.

Still again the class of machine used is an essential part of the record. The author has seen cases of job rates, fixed for lathe work, being given for the same jobs when done on capstans ; of jobs, when specially tooled, being given the same job rates as when done without special tools of any kind ; of jobs done on planing machines, with two heads, being given the same job rate as when done on machines with one head ; of drilling operations, where the same job rates have been given when the work has been performed on single, as on multiple spindled machines. It is possible to illustrate similar happenings from very many sources.

The trouble does not end with an individual mistake ; although the time for each job is estimated independently of others, consistency of job rates is much to be desired, and, should comparison be made with job rates which have been muddled by being allowed to stand although the methods have been changed, the cases are at once weakened, and, as many firms know to their cost, much trouble has ensued in consequence.

There is no doubt that next in importance to fixing accurate job rates is the need for precise records. In making these up, it is well to bear in mind that they may be called as evidence in the case of disputes over the supposed cutting of job rates, and that, in this event, they should be so clear and definite that not only will their submission shew clearly what has been arranged for, but will tend also to inculcate a feeling of trust and confidence in the minds of the workers that there is a real and tangible basis in every case.

The form in which this record is to be built up will depend, to some extent, upon the size and lay-out of the works, the nature of the work being done, the method of control adopted in connection with estimating and rate-fixing, and the use it is desired to make of the records being provided. Thus, in a small works, or even in a large works compactly laid out, the records could be centrally kept, while in a large or straggling works it may be necessary, for purposes of economy of time, that the records shall always be available in the department to which they apply.

It will be obvious that, if the record is to be complete, the estimate itself must be included, because that is the basis of everything in connection with the job rate. This is not always appreciated, and in many instances the estimate is treated as little more than a scrap of paper which, when the result of the calculation made has been copied on to some form of summarized record, can be dispensed with. This is not the case ; a mere record of the job rate even though the minutest detail be included is of no value if the basis is being questioned nor if such basis is required for comparative purposes for some other operations. A first step then is the preservation and accurate filing of the individual estimate.

There is no need to specify any particular size of paper to be used for estimating purposes, but the advantage of a standard size of paper, if only from the standpoint of economy, will be obvious and a suitable size and form will be found to be $8'' \times 5''$ tear-off pads. These pads can be of plain paper or, if desired, the heads may be printed, although, if the estimating be done in the office, there will be no need for pads to be used. On these, free-hand sketches can be made to indicate the shape and size of the piece being worked upon and the extent of the operation. When found necessary, the portions to be machined can be over-lined in, say, red or green, to indicate same, one colour to be used for roughed the other for finished faces, etc. The class of material should also be stated, together with its form, the type of machine used, and, if needs be, its number and the drawing number, and these particulars, together with the estimate itself, drawn up as shewn in the various chapters on production estimating, would enable a complete record to be made of all that was involved in connection with that particular operation as regards job rate. No specially designed form is required, at the same time there is an advantage in having all estimates drawn up in one manner, if only for convenience in checking and filing.

It is possible for the filing to be done in different ways ; under the departments in which the operations are done or, it may be, in the actual departments concerned ; under processes as milling, drilling, turning, fitting, etc., for the convenience of rate-fixers ; under classes of products as bushes, spindles, brackets and so on for the purpose of comparison of overall times or costs ; or directly under drawing numbers. Special circumstances may favour either one or other of these, but whether the filing is done centrally or in the department concerned it will probably be found that, where costing and estimating are done by the rate-fixing department, the most frequent cause of reference will be in connection therewith, consequently the most convenient order of filing will usually be under drawing numbers.

Where the rate-fixing department is supplied with a set of drawings, these can conveniently be filed under like types as bushes, brackets, etc., and, if some distinctive reference be given such as a

class number and the estimates be marked accordingly, a good cross-reference would be provided.

The method of filing the estimates hardly needs discussion. The most convenient perhaps is to file in ordinary cabinets, behind guide cards, indicating as frequently as may be necessary such numbers as will shew the approximate position of the estimate required. It will be apparent, however, that some more ready means of reference as to the operations and job rates of all pieces will be needed than that of the individual estimates ; even if not, the estimate itself requires preservation, and too frequent reference would soon render it so dilapidated as to be difficult to handle and decipher. The form which this means of reference shall be given brings into prominence the value of planning, and this, in turn, has an important and far-reaching influence on the manner in which the rate of output is to be estimated and on the methods for the supervision of same.

There are two distinct policies which can be followed in connection with rate-fixing: (1) to prepare the job rates before the operations are put in hand ; (2) to estimate the rate of output after the operations have been commenced. The policy followed will be largely dependent upon whether operations are planned or not. Thus, if no attempt be made to determine operations before manufacture is commenced, it will be obvious that job rates cannot be fixed in advance and must follow the commencement of each operation. In such circumstances the estimating cannot be done until the estimator has visited the worker for the purpose of ascertaining the details of the operation and the conditions under which it is to be carried out. The estimate may then be made out on the shop floor or in the office, but, because the work is in progress and because, also, of the necessity for the job rate to be fixed as soon as possible, the fixing of same is always an urgent matter, in connection with which no time should be lost.

On the other hand, where the operations are decided beforehand, together with the class of machine to be used, it is possible for the rate of production to be estimated likewise and for the job rates to be ready before the commencement of the work. This is a question upon which much divergence of opinion has existed, but many sceptics have been converted, and firms who have tried and dispensed with this predetermination of methods and rates have been forced back to its use by the influence of competition.

If a little logic be brought to bear upon the matter it will be apparent that, if tenders are keenly competitive, that tender is likely to be successful in obtaining the contract in which the lowest price is quoted. As no firm can continue in business for long by quoting prices which are too low, it follows, further, that the prices quoted, generally, will be likely to represent possibility of performance. This being so, the basis of the tender, the estimated figures, must also represent possibility of performance in detail, and must therefore be approximately correct and be suitable for use in fixing

job rates. The fact that tenders, which are successful in the gaining of contracts and enable a profit to be made by their discharge, can be estimated is a proof in itself of the possibility of fixing job rates in advance.

The argument is not put forth solely for the advantage, supposed or otherwise, of fixing job rates beforehand. While there are undoubted advantages to be secured, if only by the publication of the job rates so fixed, which gives an appearance of permanence and should tend to inspire confidence among the workers, the real value lies in the control which can be exercised over the job rates before they are issued to the workers as such. Not only so, but by the methods of production being predetermined, a much more effective control can be exerted over manufacture than is otherwise possible. It is not always appreciated, probably, but one of the weaknesses of engineering production is its negative inspection, and one of the causes of negative inspection is lack of instruction. By the means of the predetermined operation and its notification to the shops, precise instructions can be conveyed to inspectors as to the condition a piece of work should be in at the conclusion of each operation, and this strengthens the position of the inspector and tends to lift the standard of work at the same time.

Thus, for roughing operations, the amount to be left for finishing, whether by grinding or other process, can be stated ; the same when scraping is necessary, precise instructions can be conveyed as to the maximum amount of material to be left for the fitter to remove. It may be said that this can be done by the medium of the drawing and the stating of tolerances, but this is not so. If all the tolerances which were required for every operation were quoted, some of the drawings would be such a confused mass of figures that their deciphering would be a matter almost of impossibility.

This defining of the standard of finish required, as well as of the details of operations, not only enables a greater control to be kept over manufacture, but also facilitates the fixing of job rates, in that the conditions laid down should obtain, and, when they do not, a complaint from the worker will indicate that something has not been done as it should have been, and this will enable suitable enquiries to be made as to the reason for the fault and the necessary steps to be taken to prevent a recurrence. A further advantage is that estimating can be more readily specialized when done in the office than in the shops. All milling operations can be estimated by a miller, lathe operations by a turner, and so on, so that the specialization of the trades would be turned to the best account for administrative purposes.

At the same time, this question of predetermination of operations and job rates is one which cannot be decided upon theory only, however clear ; while there can be little doubt as to the advantages to be obtained, particularly with large or intricate pieces, the availability of plant is a big factor, and, excepting with work

of a repetitive character, expert local advice is necessary in arriving at decisions. To lay down a sequence of operations and issue same to the workshops is a waste of time, excepting such is rigidly followed, while, if to insist on a rigid observance meant that owing to the specified machines not being available, others on which jobs could be handled must stand idle, such an arrangement could be a handicap rather than an aid to production.

Where the conditions are such that operations and job rates can be conveniently arranged beforehand, it will be necessary that the rate-fixing department should be supplied with copies of drawings as soon as possible, because in the planning of operations is decided the form of the material to be used, and its amount, as with plain or extruded bar, or forgings, stampings, or castings, and not until this has been decided can requisitions for material be passed through. Then, in order to facilitate the requisitioning of material, planning should be carried out, without waiting for the estimating of the rate of production, those pieces being handled first which would take the longest time in manufacture or for which difficulty in obtaining the requisite material was anticipated.

This being done and particulars of the material requirements being forwarded to the Ordering Department, the fixing of job rates can be proceeded with on the lines laid down in the various chapters on production estimating. When estimating is done in the office, particularly if done before the commencement of manufacture, several matters become simplified. Not only is the urgency less, but, also, time is available for checking the estimate for clerical and technical accuracy, enabling the experience of the Chief Rate-fixer to be more usefully felt, both where accuracy and consistency are concerned.

This is a direction in which much looseness has existed. When job rates are fixed entirely in the shop, it is not uncommon to find that no attempt is made to check same until after they have been passed to the worker and, sometimes, not even then. The policy is a mistaken one, and, while geographical conditions may make for difficulty in some instances, much more satisfactory arrangements are possible, with but comparatively little expense.

Where a works is so large or straggling that it is not a practicable proposition for all the rate-fixers to be centralized in one office, it will be found profitable, in many instances, to subdivide the works into sections and to appoint senior rate-fixers to take charge of each section, deputizing the chief rate-fixer on such questions as the passing of job rates. Where such rates are obtainable from standard data or tables, this reference may possibly be dispensed with, but in other cases the issue is of sufficient importance to justify the second opinion being secured.

The question remains as to the nature of the records which the estimator is to use where operations are not planned and where the job rates are estimated in the shop. It follows that, in the latter case, every operation commenced must be seen by an estim-

ator and that only after ascertaining there is no job rate would estimating be put in hand. To enable this to be readily ascertained, a record of old jobs must be available in handy form, which will give such particulars of the operation and its method of performance, together with the job rate fixed, that will enable recognition and verification to be readily possible. This record must be in book form, either loose leaf or bound. While the former is the most convenient, a bound book, suitably indexed, is the safer plan, and will provide the most permanent record, and one that is most difficult to interfere with. Such records, however, will obviously be departmental and sectional rather than inclusive of all operations on one job, and therein lies one of the weaknesses. It is unavoidable, however, where the rate-fixing is done in this manner, because the chief object of the record is to supply departmental requirements and not, necessarily, complete sets of information, either of operations or of job rates. The question of the technical qualifications of the estimators themselves renders this advisable, if not imperative.

With the fixing of job rates, even as with the performance of the operations themselves, specialization is bound to operate. Thus in a large department, where the work is not of a highly repetition character, several estimators may be needed, and it is but following the dictates of common sense for the machining work to be estimated by a machineman and for fitting work to be handled by one who has been a fitter. To do otherwise would be to expect a fitter, who may have no practical experience of machine work, to estimate the rate of production, when his ignorance of that work would prevent him forming an intelligent judgment as to what may be actually required or possible. Then such a distribution of work as the following is easily possible.

A large engine cylinder may be marked off for machining in one department ; be planed, or milled and bored in another ; be re-marked off in the first dept. ; be drilled and tapped in a third ; and fitted and assembled in a fourth. True, all these departments or sections may be under the same roof, but even as different foremen would be in charge of the different sections of the work so may different estimators be required. The record of the operations would then be found in four different books. It may be suggested that each book should hold a complete record, those operations and job rates not handled by one estimator to be obtained from others ; but this is not practicable, and excepting an attempt be made to build up a complete lay-out of operations, same to be centrally filed, there is no option but to rely on records as contained in the different books. These, brought together when called for, will enable a check to be made to make sure nothing has been overlooked, but this at the best, when the manufacture of intricate pieces is concerned, is but a poor substitute for the properly planned lay-out. A further weakness is that, when such a record has been prepared, it is nothing more than a record of what has been done ;

it is binding on nobody, and the foreman's record of what he did being mental only is quite likely to be departed from the next time such a job is done.

The class of book to be used and the method of entering the different operations is of some interest. It will be evident that the limitations of a bound book will be more quickly reached than will the capacity of a loose cabinet filing system, and the entries need to be made in such a way that a book will be filled as nearly as possible in every portion, before a second one is commenced. Broadly speaking, there are two methods, one of filing under drawing numbers, the other of filing under names of parts. Each of these, however, calls for some method of division or indexing, otherwise there would be no order in the manner in which the entries were made.

Taking the latter first, to record under name requires some rule as to nomenclature, and as soon as this is touched a world of confusion is revealed. In this respect, perhaps, the War Office is deserving of real praise for their plain and exceedingly useful lead. In many works, a cylinder is a motor cylinder, a high-pressure or low-pressure cylinder ; a shaft is a main shaft or an auxiliary shaft ; a bolt is a holding-down bolt or a connecting bolt, and many entries are made in accordance with the first name mentioned ; the result is confusion. The War Office method, however, is to place the name of the part first as cylinder, shaft, or bolt, giving its description afterwards as cylinder, motor ; shaft, main ; bolt, holding down. This method is the only sound one, and if followed rigorously will be found to give satisfactory results and, so far as there is an advantage in this, similar jobs are likely to be entered under the same index letter. A freehand sketch in perspective will improve the value of the record and facilitate their recognition by new rate-fixers.

In some cases, however, as with small drilling operations, the entries required may be so numerous and the operations so stereotyped that descriptions and sketches are unnecessary, and nothing further than a record of the size and number of holes drilled and of the job rate against the drawing number is required. Then some convenient method of entering numbers may give better results than that of entering jobs under names. Many schemes have been tried, some of which are quite novel. The difficulty is, where the drawings in use are large in number, that ordinary methods of classification are likely to call for too much space. Thus if one page of a book were allotted to every block of 100 drawing numbers, as from 1 to 100 on a page, 201 to 300 on another, and so on, and there be a range of 10,000 drawings, 100 pages would be required; but, while these are not many really, it would be found that on some pages but few entries would be made while others would be filled up and the scheme would at once begin to fail.

One method used is to add all the digits in a drawing number and to make the entry under that number. Thus if the drawing

number were 7862, the total of these added together would be 23 and the required entry would be made under that number. The method is quite effective provided no mistakes are made in addition, but if a mistake be made, to pick up an entry means complete search.

Another method is to enter under the last figure of a drawing number as 7862 under 2, 16735 under 5, and so on. This is somewhat safer than the previous method described, inasmuch as calculation is obviated and the entries required are likely to be well distributed. A sub-division can be made if required by entering the four-figure numbers on one page and the five-figure numbers on another page.

The type of book to be used allows of little latitude except as to size. Some method of indexing is obviously necessary and books with an alphabetical index can always be obtained. The quality of the binding of most of the books on the general market, however, is, usually, not good enough, the continual use rapidly wearing away the backs of same so that rewriting soon becomes necessary, a task of no small proportions. It will be found most economical in the end to have books specially made, both as to covers and ruling, and also as to the number of pages per letter of index. Thus under "B" many entries are likely to be required; brackets, bushes, bearings, etc., while under "A" the requirements may be but few. The number of pages to be allowed for each letter will depend upon the product and the nomenclature.

A standard size of page should be adopted, but different numbers of pages per book can be provided. There is an advantage sometimes in reserving one book for one order or for one class of work. Then in the case of work of a class or design which is not often repeated, books holding such records can be put by until required. Below is shewn the facsimile of a page of a book suitable for the purpose.

Order No.	Part and Drawing No.	NAME OF PART—SKETCH—OPERATION.	Est.	Job Rate.	
					D

FIG. 15.

An objection to the book system is the difficulty of supervision or checking. The books are always in use, and when no check is

made the tendency is to encourage slackness, and it is not uncommon to find that the entering of records is much in arrears. In this connection it is advisable that the pads, issued for estimating purposes, should be numbered and recorded as to whom issued, and that no estimator be allowed to have more than two pads in use at one time, the one in use for estimating, the other, completed, and full of estimates being retained for purposes of entering in the record book.

Owing to the importance of records, it is desirable that an occassional check should be made to ascertain if those made are clear and concise. This is a duty which the Chief Rate-fixer or a senior assistant should discharge. Such a check has a useful moral influence and encourages an efficiency which is essential. All record and data books should be kept in a fire-proof safe at night, each book being checked in and out. Loss can then be quickly noted and enquiries can be set on foot at once. The possibility of a loss of this kind, however, is real, and is but another pointer to the undesirability of the method. In Chapter XVII. the method of notifying the worker of his job rate is dealt with, and this has a bearing on the question.

CHAPTER XX

JOB RATE ADJUSTMENT

In the adjustment of job rates have been centred many of the difficulties experienced in connection with payment by results, although, to a considerable extent, these have reflected the nature of, and the reasons for, the adjustments being made. Owing to the unsatisfactory manner in which job rates had commonly been based, adjustments have usually been in the nature of reductions, and seeing the need for these has so often been disclosed by the size of the earnings made, the object of the adjustments has usually been to reduce earnings. While the aim in the first place should be to fix job rates which reflect efficiency and, therefore, should not require adjustment for purposes of correction, the need for adjustment will never be obviated, it is called for by so many different causes.

Adjustment may be needed because methods have been modified as a result of the use of improved tools or machines ; it may be found necessary, in order to facilitate delivery, for operations to be divided, using similar or, perhaps, different methods for a part or the whole of the work ; again, if the basis of the job rates be that of analysis and calculation rather than of trial, the rates fixed may not always be considered sufficient by the workers and complaints will be made accompanied by a request for revision.

This latter phase of the question is one deserving of the most careful consideration. In those instances where rates have been fixed as a result of actual trial, then, so far as the workers generally are concerned, the fairness of job rates has been demonstrated. True, such demonstration is a one-sided one and safeguards the interests of the workers only, the consequence being that exorbitant job rates are fixed, to correct which reduction seems the only remedy. The abolition of this method of fixing rates, however, does not necessarily obviate all the trouble therewith, but like most changes is accompanied by difficulties of another character. With varying ability amongst workers and with job rates fixed by " doing them on paper," the methods used not being understood or trusted by workers, more particularly so when new work is concerned, it is to be expected that complaints will be made

on the score that new job rates are not sufficient, and some effort must be made to meet those complaints in a spirit of discussion, rather than of authority, and of reasoning, rather than of bargaining. The day is gone, and rightly so, if intelligent men are to be encouraged in workshops, for blind obedience to authority to be expected, and not only this, it is a contradiction in spirit of the whole principle underlying payment by results.

The object underlying payment by results is to induce the best output by encouraging the workers to put forth their best efforts, and is an admission that good-will is more potent than authority. Therefore the aim must be to fix job rates which, as well as making efficient costs possible, will also make the contentment of workers possible ; this latter is not ensured by a display of authority any more than it is by its absence ; the secret is trust and confidence born of fair dealing and, in the absence of proof by trial, some other basis becomes an absolute necessity.

It may be said that the proof of the pudding is in the eating thereof, and that the best way to settle questions of this kind is for the job to be done, both parties to abide by the result. This has been tried and not always with success. So far as the manufacturer is concerned, the test by a worker is likely to embody, and not unnaturally, the desire not to do the job too quickly ; in such a case, on the one hand, the worker has to face the unfavourable comments of his fellows should he be too successful, while, on the other hand, he fears for his job should the manufacturer think he has taken too long.

In the cases where the manufacturer keeps one or more members of his staff to try out disputed jobs, workers think that the men chosen are experts, and that it is most unlikely that the average man, or, in fact, the man making the test, would be able to maintain the output on the basis of the test performance. It is thought that there is no real reason for fear in this connection, because, excepting special machines are set aside for the purpose of demonstration, the unfamiliarity of demonstrators with general machines could counterbalance, possibly, in the majority of cases, any special expertness which otherwise might be present. In most cases, excepting with operations of a purely mechanical character where the exercise of special skill was not required, it would be necessary to do large batches of work if the results were to be at all satisfactory. It is suggested that demonstration as a means of settling disputed job rates is not, in the ordinary way, a satisfactory solution ; it has been proved to have real value, but, in so far that proof thereby is obtained by the display of personal skill, the result, when the worker is proved wrong, is often received with some bitterness. Other methods can be used and are really more desirable, particularly where the operations are long in duration of time or the quantities are small.

One real advantage of the methods advocated in the succeeding chapters is that a definite arguable and detailed basis is provided,

which enable any part of an operation to be discussed. In machine work, for example, if the cutting be estimated to be done at 60 feet per minute, using 16 feeds per inch, with cuts .25 of an inch deep, it is not a question for discussion, or of demonstration as to the time required to do all the cutting, or of the ability of the worker, it is rather a test of the cutting capacity of the machine and the tools provided. If these fail, the estimate on which the job rate has been based in that particular direction will be on the low side and will require revision on the lines of the results obtained, and, while such a mistake should not happen at all, the test made will enable the repetition of a similar mistake to be avoided; really tests of this kind are not undesirable as leading to the building up of a volume of approved data known to workers as well as to members of the employers' staff.

These methods have been tried and have proved eminently successful, and, after 20 years' experience in these matters, the author has been forced to the conclusion that, given a fair proposition with a definite basis which can be discussed with a worker, the troubles with job rates largely disappear. There are exceptions where workers set themselves out deliberately to deceive those responsible for fixing such rates, for the purpose of obtaining rates of higher value than the work justifies, but these are found usually to be in a very small minority and, inasmuch as such men have a wrong sense of perspective, they are often easily dealt with. Two cases of different kinds may be cited as indicating the possibilities in this respect.

A fitter was working on steel doors and complained that the job rate given was insufficient, saying the job could not be done in the time allowed. The work consisted largely of chipping, marking off, tapping, and riveting. The man was not disposed to discuss the job or to give it a trial, and, while it was known another man was already making the same job "pay," it was not the policy to put one man against another on new jobs of this kind. Record of this particular man's work on similar jobs were looked up and a few which were representative were taken, when it was proved to him that the job rate given was not only in accord with others, but that in making these other jobs "pay," he had proved the data correct on which the job rate in question had been based. A few days afterwards the same man said to his fellows that "he did his best to get more time but couldn't and must make the best of a bad job," but he was very much perturbed when he learnt that it was known that, at the time of the discussion, the other fellow was making the same job pay which he said could not be done in the time, he being jealous for his reputation.

In another case, a job rate of 105 hours had been given for the turning of a shaft, the time in which it was estimated the work should be done being 70 hours. The operation had actually taken 110 hours and a complaint was made, the turner being somewhat contemptuous of the ideas of the man who had fixed the job rate.

He was asked, however, if he could describe exactly what he had done, the speeds and feeds used, the depth of cut, and the number of cuts taken. The answer was in the affirmative. Further, could he give an idea as to the time involved in putting the job in and taking it out of the lathe, for changing and setting tools, for starting cuts, and for gauging. Again the man thought he could. Still further, was he prepared to give these particulars and so enable a new rate to be calculated on the basis of what he had actually done. The answer was again in the affirmative. The job was dealt with on these lines; the man was prompted regarding several items which he had overlooked or did not think worth mentioning; for some items the time suggested by him was too small and these were increased. Every effort was made to prevent the man being unfair to himself. The result shewn by building up the estimate in this way was a job rate less by 10 hours. The man was astounded, but after checking the estimate he stated, "Well I have agreed the job ought to be done as I have stated, speed, feeds, and so on, and while I can't understand where the time went to, I'll give it a good trial on the next one." The job rate was not reduced because of the new estimate, and the result of the trial was that the time taken was reduced to 75 hours, the man expressing himself as satisfied with both his rate and his treatment.

The Appeal System. Some rather elaborate arrangements have been made for dealing with complaints regarding job rates, but, while any idea should be considered, which appears likely to enable friction on these matters to be avoided, the sense of proportion should not be lost sight of. The first question really is to ascertain the true position. Is it one of supreme discontent? If so, what is the reason? Can it be remedied by the removal of the causes, or is confidence so far destroyed that some safeguard must be erected? Generally speaking, it will be found that the position taken up by the workers is a defensive one and, accordingly as their experience is considered by them to be unsatisfactory, the stronger will their defence be made. After all this is but logical. It will be a mistake, however, to assume that because the defence in some works has had to be of this strenuous character that such is the position in all works. That is not the case.

One such arrangement is known as the Appeal System, and was introduced by agreement into the Barrow Works of Messrs. Vickers during the Great War. The particulars of the arrangements, which were published in the daily press at the time, are given as an appendix at the end of this book. There is nothing in the provisions of this agreement to which objection need be taken, and so long as the fixing of job rates, which will not prejudice the obtainment of economical production, is not overshadowed by the importance of keeping the Appeal System alive, some good can follow its use.

It is advisable, however, that the probable effect of the use of this war-time measure on peace-time productions shall be considered before it is adopted. In normal times, in most works, the

difficulties experienced with workers over job rates have been in connection with reductions and inconsistencies rather than with unwillingness to accept job rates which are fair and consistent. In these circumstances a firm would be exceedingly foolish to allow such cases to go to appeal—they should not allow them to arise—while, if new work of an ordinary character be involved, proof is generally easy without undue difficulty.

In its early days, the existence of an appeal section is looked upon by the workers as being somewhat novel, something which must be tried, and complaints which, before its existence, would have been amicably settled in the ordinary way as indicated in Clause 4 of that system, are put up for appeal. These early days are the supreme testing time for the system. Much is expected of it, particularly by the workers. The position before an appeal reaches this stage is that the rate-fixer and chief rate-fixer—the latter usually an official of management rank—have satisfied themselves that the job rate is right and should not be increased. The men rightly or wrongly are equally satisfied the job rate is low.

Now for the appeal section to be treated by the workers as having real value, concessions must be obtained and at fairly frequent intervals; if not, the appeal section is likely to be discredited; further, if only because of their lives with their fellows, the men's representatives are encouraged to stand up for the appellants. Consequently, the decisions arrived at are likely to be prejudiced if only for the political reason of keeping the appeal section alive. On the other hand, should the decisions made reflect the facts only, and the fixing of job rates be intelligently and equitably done, the results to the workers would be considered by them not to be worth while and the appeal system would die a natural death through non-use.

The author has sat as the chairman of such a section and has been told by the workers' representatives that they were quite satisfied that the decisions given were fair; that they could but admit that some of the cases put up were merely attempts to obtain higher job rates than were justified; that although the men knew this, they, as representatives, were expected to obtain concessions, and that they did not propose to have any more to do with the scheme. One of the incidents which led to this decision was a claim that the job rates allowed for welding were too low. After much discussion it was agreed that representative jobs should be tried by different workers, the choice to be agreed, and the results to be considered in their entirety. In each case the results went to justify the job rates which had been given, incidentally killing the appeal system in that department.

In another case where, acting on the instructions of the Directors, the appeal system was offered to a large department, the Shop Stewards stated that they saw no need for it; the complaints of the men were always listened to and, they thought, satisfactorily dealt with; when that situation was changed they would consider the appeal system.

It is believed, as shewn in the examples quoted on page 205, that the most satisfactory plan, in dealing with job rates which are queried as to their sufficiency, is to have a sound arguable basis for same, and that, when this is provided and discussed with the worker, the chances of a satisfactory decision are at least as real as when the number of directly interested parties is increased. The great aim must be to build up and to maintain a reputation for fair dealing, and this, in normal times, will be found to be the best guarantee of peace. In the desire to keep an appeal system alive much harm can be done, costs being endangered as a consequence.

One advantage of a system of this kind which should not be overlooked is that a definite outlet is provided for the ventilation of complaints. Where complaints, whatever may be their nature, are ignored or receive unsatisfactory treatment, discontent is encouraged, and this, suppressed for a time, can become such a serious matter that, in order to save the system of payment in force, special arrangements become necessary. For such a position to arise is a direct reflection on the personnel, to the choice of which too much attention can hardly be given.

Change of Methods. It is a rule laid down and agreed to by the representatives of both the Trade Societies and the Engineering Employers that job rates once fixed shall not be altered excepting the methods are changed. This is a necessary rule, but it has often been kept in the letter and broken in the spirit. On many occasions when job rates have been found to be on the high side, operations have been split, put on to different machines and new job rates have been given ; no reduction in the amount of work has been made—in some cases reduced output has been unavoidable—but " the method has been altered and a new rate is justified." In other cases slight alterations have been made to drawings, new drawing numbers have been given, again, so it has been claimed, justifying new job rates. These are tactics which cannot be supported as being honest, and it is not surprising to find that changes in method are often viewed by workers as being mere subterfuges for cutting job rates.

The policy in the long run proves to be a mistaken one, working much more harm than good, and has been the source of one of the common complaints made in connection with payment by results.

While the apparent need for subterfuge of this kind to be resorted to is again an argument that correct job rates should be fixed in the first place, it does not follow that a mistake made need be regarded as irretrievable or that operations on which large earnings are made should not be modified. The practice the author has found to give satisfaction in this respect is to make sure that the altered method is a quicker one and therefore justified in any case ; then to arrange the new job rate so that the opportunities for earning are at least as good as before the change was made. Thus if time and a half were the average earnings, when using the old method, the job rate for the new method should be so fixed that the same

percentage of extra pay could be earned. Under this arrangement no difficulties were experienced and no inducement to restrict output was presented.

It is necessary, sometimes, to split operations, for which job rates have been fixed, into two or more parts, or to modify one portion of an operation by the use of an improved tool. Such modification can be conveniently handled under the methods laid down, because of the detailed manner in which the job rate has been built up. If, for example, for a shaft, bar material be replaced by forgings, a certain number of roughing cuts will not be required, and the time allowed for these together with the amount allowed for handling can be deducted. It may be decided to take the tapping out of a combined drilling and tapping operation ; the time for tapping and the requisite handling can be taken out of the estimate without interfering with that allowed for the remainder of the work.

Special Allowances. The policies followed in different works in the recognition of special difficulties and making allowances for same vary considerably. In some cases the worker is told " that what he loses on the swings he must make up on the roundabouts." With petty difficulties this policy might pass muster, but in principle it is entirely wrong. It is to a firm's benefit to treat the job rate as being something more than a bribe to induce workers to do more work. The line taken should rather be that the basis of the job rate signifies a rate of output below which rate the firm will not be satisfied, and that the extra wages paid are a recognition of the successful endeavours made to give that rate.

For this attitude to be taken seriously, however, it must be recognized that, if more work is involved than the job rate has been arranged to cover, the output rate will be affected also, and that a review of some kind is necessary. There is no doubt about this, nor about the eventual economy in so doing. So soon as workers learn that estimates of output mean, approximately, what they stand for, a moral regard for the same will grow up which will have its business value to both the men and the firm.

In making allowances for conditions which are special, it is necessary that their special nature should be stated and also the reasons for same. For this purpose, any allowance made should be kept separate from the job rate always. It is not a part of the legitimate job rate, and should not figure as such, and steps should be taken to obviate the need for its repetition ; otherwise it can be treated as being a regular thing and be looked upon as a part of the job rate. This latter is not an uncommon experience of which the following is an example.

An allowance was made to fitters to cover the correction in their operation of faulty machining. The error was not attended to for some weeks and, when the fault was remedied in the machine shop, the rate-fixer in the fitting shop was not notified, and the allowance was continued until it was claimed as a part of the job

rate. To avoid happenings of this kind, it is desirable that a daily return should be made by the rate-fixers of all allowances given with the reasons for same, and that the departmental foremen responsible for the work for which the allowances were required should be notified, their comments being asked for if considered advisable. This should tend to ensure the temporary nature of allowances being maintained.

In making allowances, if additional cutting be involved as with extra material ; if slower speeds be necessary as with hard material : if finer feeds have to be used owing to the machine being unsuitable, or whatever may be the cause, the basis of the allowance should be calculation, not guesswork. Thus, if an extra rough cut be required the basis of the allowance will be the estimate, and the time allowed therein for similar cuts ; if hard material be encountered and a slower speed has to be used, the basis for the amount of the allowance will be the difference between the time per cut worked out in the estimate and that which is actually necessary.

If fitters' work be involved, the procedure is similar. If more material has been left for finishing than is normally required, an allowance should be made for the removal of that material which is surplus, but as such. For example, it does not follow that if the amount of material to be removed is twice that which is necessary that the time involved will be doubled thereby, and this applies with hand work as well as machine work. If, for example, .003 of an inch be ordinarily sufficient to allow a face to be scraped to a fine finish, this operation actually covers roughing and finishing and the removal of the last half thousandth takes nearly as long as does the remainder. This is dealt with more fully in Chapter XXXI., but it is important that the relative time value of roughing and finishing operations should be borne in mind when allowances are being made.

Allowances for Small Quantities. While not being adjustments in the ordinary sense of the term, the question of allowances for small quantities can conveniently be dealt with under this head. Even as there is a big difference between the job rates based on time taken and on estimated time, so can there be a difference between actual output and estimated output, more particularly at the commencement of a new operation. With jobbing work, while its influence is the same as with that of a mass-production character, its significance is less, because the opportunity to acquire that measure of efficiency which comes with the handling of quantities is not afforded. With mass-production work, however, the difference in output at the beginning of an operation and when it has been running a week or a month is sometimes most marked, and job rates, which, when the operation was started, may have appeared to have been on the small side, may in a few weeks be proved to be altogether too high.

The methods of dealing with this question vary considerably, and in some instances are quite unsatisfactory. It has been re-

iterated that the object of making payment by results is to induce the best efforts of the workers for the purpose of obtaining production at efficient cost, and it is in keeping with the spirit of that aim if that line be taken which is calculated to induce that the best output, even though the job rate with its allowance be definitely higher than the estimated cost.

Let it be assumed that a new operation is started, the output of which must not be less than 10 articles per hour if there is to be no loss on the estimated price, but that, owing to the work being new, 5 articles per hour only are being turned out, indicating a loss of some magnitude. Further, let it be assumed that the indications are that the obtainment of 10 articles per hour will be delayed for some weeks and that, at the rate of 8d. per hour, there will be a loss of 15/8 weekly per operator, labour only. What method is best calculated to induce efficient output with a minimum of delay ?

In some works new operations are done under the time system, either for a stated time or until the degree of efficiency obtained is sufficient to make the job rate fixed appear to present a possibility of earning extra pay. Again, special temporary job rates are used, same to stand for a definite period, as, say, 1, 4, or 12 weeks, a fixed job rate then to be given, the same not to be influenced at all by the amount of the temporary rates. In other cases the job rate is fixed and then gradually raised until the " required " efforts are put forward, or until the limit is reached, when, not infrequently, a deadlock ensues.

Possibly the most economical of the three methods is the second. Under it inducement can be present from an early stage, and, in obtaining increased output, oncosts are relieved. Another method is possible, however, which merits consideration. Even as the output obtained will gradually be improved as the worker gets used to the operation so should the allowance be reduced until the job rate only is given. This can be done as follows, time or quantity being worked upon.

In the case of an operation on which it was estimated one month would be required in order to enable maximum output to be reached, arrangements could be made to make an allowance on the following lines:

Say 1st week - - - - - -	50 %
2nd week - - - - - -	25 %
3rd week - - - - - -	12½ %
4th week - - - - - -	10 %

Alternatively, the allowance could be made on the basis of quantities as follows :

1st 1000 - - - - - -	50 %
2nd 1000 - - - - - -	25 %
3rd 1000 - - - - - -	12½ %
4th 1000 - - - - - -	10 %

By a wise choice of the quantity or period, and the rate of allowance, an efficient and economical inducement would be in evidence which would obviate the sudden drop in earnings likely to accompany the change from the temporary to the permanent job rate. All the time the worker would know definitely what his job rate was, and by the allowance being kept separate from the job rate, and the reason for same being stated, the charge of reducing job rates should not be involved.

Faulty Material. Sometimes pieces upon which labour has been spent are found to be unusable owing to the material being faulty. In some instances the worker receives no allowance; in others, the time rate of wages is allowed, while, still further, the appropriate portion of the job rate is allowed, enabling extra pay to be earned.

There can be little doubt that the latter is the best and the fairest. The worker has no responsibility for the material being good or bad; the job rate is given for the purpose of inducing his best efforts, and when these have been induced they should be paid for, even if all the material be bad. One proviso is justified, namely, that payment should be made up to that stage only when the fault should have been discovered. This will induce workers to be careful and to call attention to faults in material at the earliest possible moment.

In order to keep the records quite clear, it is advisable that parts which are unusable owing to the material being faulty should be rejected, the reason stated and time allowed for the work done. Thus if one half of the work had been done, one half the job rate should be allowed. If the work had been completed and the fault could not have been discovered beforehand, the whole of the job rate should be allowed.

Waiting for Work, Etc. In pursuance of the policy that the job rate infers a rate of output which the manufacturer expects to obtain, it follows that everything which tends to alter the conditions understood to exist should be allowed for, and inability to get on with the work is one of these. Some firms are apt to look askance at the idea of making allowances of this kind, but a little examination of the matter will shew that it is really a sound proposition, and for two separate reasons.

In the first place, job rates are based on amount of the work to be done, and if such rates be recognized as being something in the nature of a contract, binding on both sides, the manufacturer has an obvious right to expect the requisite rate of output, and on the other hand the worker expects the contract to start, so far as he is concerned, when the work is available and to be completed when the work has been done, uninterrupted opportunities for continuing the work being understood to be provided. This is the nature of the conditions which are supposed to exist in the carrying out of contracts of all kinds, and if workers are not allowed for delays which are outside their control their opportunities for earning are affected thereby, and a feeling of unfairness is created which reacts prejudicially on

output. It has been proved, if proof be necessary for so obvious a matter, that where allowances are not so made the interest in the possibility of earning extra pay wanes, and cases have been known where it has been almost non-existent. This phase, however, is not the more important of the two. What is of vastly greater value is the moral effect on the shop supervision and the technical staff generally.

It is impossible for any works manager to have too much information regarding the efficiency of his works and staff, or the conditions of his shops as to the amount of work available. Workshops may be said to be well-run when each man paid is employed and has a suitable job that is wanted, upon which he can work without interruption, and that another job with which to follow on is ready. These conditions do not always obtain, the reasons being various; but, whatever may be the reason, the facts should be available for the works manager's information. Where the reasons are outside the control of the shop staff, the facts will probably be reported, but when, as is sometimes the case, the cause is bad organization on their part, nothing is likely to be heard.

The principle of recognizing the right of the worker to time allowances for delays of this kind, however, tends to bring such weaknesses to light, and by so doing the shop staff themselves endeavour to prevent their recurrence. One of the common causes of delay is the next job not being ready. This may be due to a variety of reasons, but it is the foreman's responsibility to provide the job or to report to his immediate superior his inability so to do.

Another common cause of delay, where heavy work is concerned, is the unsatisfactory organization of the crane service or the insufficiency of cranes. In one instance, the position disclosed by the allowances required, because of "waiting for crane," was such that a special investigation was made and a new crane was provided as a result.

"Waiting for machine-setter" is also a frequent trouble. This may be brought about equally by inefficient setters as by an insufficient number, but, excepting the delay be shewn up, no record will be made and the shortage of output will be held to be idle or incompetent operators or that job rates are low.

In one workshop, complaints were made by one of the machine-setters on a group of capstans that the job rates allowed, generally, were insufficient, and that the operators, unable to earn extra pay, worked but indifferently. The matter was investigated, when it was found that the job rates were sufficient, that low output was due to waiting for the machine-setter, that the number of machines looked after and the jobs handled did not constitute more work than was being satisfactorily handled by other machine-setters, and that the real trouble was the inefficiency of the complainant himself. The delay occasioned by waiting of this kind was booked from then onwards and an appreciable increase of output followed.

The method of making the allowance for waiting should be different to that which is followed for allowances of a different character. Allowances which are necessitated because of contingencies of manufacture can reasonably be made on the card for the job itself and be allowed to enter into the cost, but with waiting, normally speaking, the reason is bound to be one of organization or of policy and the cost of same should be kept entirely separate from the ordinary time taken, and should be booked as " waiting " against the appropriate reason on a separate time card and be treated as an oncost. By so doing all the time spent in waiting can be shewn up in the books, its amount and value can be readily seen, and enquiry can be made as thought necessary. An example may be interesting as to the possibilities in this connection.

A firm was disappointed with its output generally and called in outside advice as the best means of obtaining an improvement. After careful investigation it was discovered that, owing to faulty shop organization, the batches worked upon were smaller in number than need be, that the " next " jobs were rarely ready, and that, with the time lost between jobs and in machine setting, a large proportion of time was being wasted. The shop was working on the time system, and waiting cards had not been allowed. Their introduction was resented somewhat, but the matter was pursued and their use insisted upon, the results being apparent in output taking an upward tendency. Similar happenings take place under systems of payment by results, and these can be combated best by their open recognition.

Viewed broadly, the adjustment of job rates is a matter of the provision of an arguable basis by the employer, and of the observation of common sense and fair play by employer and worker alike, in the light of knowledge of possibilities which both parties should have.

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CHAPTER XXI

THE MULTIPLE MACHINE QUESTION

ALTHOUGH the question of the operation of several machines by one worker does not come exactly within the scope of this work, yet, at the same time, the decision as to whether and when it is economical for more than one machine to be worked, rests largely on the rate of output obtained and the cost thereof, and seeing the question must be discussed in connection with the fixing of job rates and can affect more than one class of machine, it has been thought advisable to deal with it separately, as a result of which the discussion can be on somewhat broader lines than would otherwise be the case.

Generally speaking, the question is one around which much controversy has been centred, and the existing attitude of the organized worker is to a great extent an abuse of power rather than a recognition of any logical argument. There are machines and classes of work where it would be folly to ask for more than one machine to be worked at a time but, wherever long periods of cutting are concerned, where the attention required is practically nil and the worker concerned is otherwise idle, there appears to be no logical reason whatsoever why such idle time should not be usefully occupied. The position is somewhat analogous to a housewife who says that because she is cooking potatoes and has to see that they are kept boiling, she cannot cook, at the same time, either another vegetable or a joint of meat or a cake. It is appreciated that the practice is open to abuse, but any tendency in this direction would shew up in spoilt work—loss of material and of the wages paid for all the labour which had been spent upon it, and this would prove to be one of the most efficient safeguards.

The question falls for decision very largely into the consideration of the nature of the operation to be performed. Where the attention of the worker is required for the greater proportion of the time, as with important finishing operations, there is no need for discussion; where irregular shaped pieces are being machined and care is required to guard against cutting into "shoulders" and the like, there is room for the exercise of discretion; but

where many rough or roughing operations are concerned, where the exercise of skill or the demand for attention is practically nil, there would appear to be no reason why more than one machine should not be worked—looked after—by one man. There are many rough turning, repetition shaping, milling and long planing operations which require but a small percentage of the worker's time, either in the actual handling of the pieces or by the attention otherwise required; in fact, where a number of machines are worked by one man, the difference between working 1 or 4 or 6 machines is, quite often, no more than that of putting 6 pieces into 6 machines instead of 6 pieces into 1 machine, and in the same time. Decisions on this score are certainly not made because the question of the exertion or attention required has been considered; the operators of hand-feed machines, and in fact of many small machines, together with bench hands, are called upon to put forth much more continuous effort than is the case with those who work the larger machines.

The practice of working more than one machine is widely recognized, however, in connection with certain classes of machines, amongst which may be mentioned milling machines of the Lincoln type, plain horizontal milling machines, deep boring machines, and some of the automatic machines, both turning and gear-cutting, while, in some districts, shaping machines with two heads, lathes, and in some instances, heavy drilling machines, more particularly of the horizontal type, are so worked.

Nevertheless, although this is true, opportunities for real economies are being lost, for various reasons, and the question is one which is worthy of discussion, if only to bring out some of those points which are often overlooked; to indicate some of the considerations which really are necessary in the interests of true economy, as distinct from apparent economy of manufacture, and to bring out the fact that the working of more than one machine by one man is not necessarily the same proposition to-day that it was twenty years ago. Improvements in cutting steels have altered the position to a considerable degree, and many an operation which at one time could have been economically done as one of a number using several machines, would result, if the same practices were followed to-day, in a restriction of output.

The practice is productive of the greatest economies, as the time taken for the cutting portion of the operation exceeds that required for handling, and the number of machines which it is possible to look after reflects this fact. Thus, theoretically speaking, if the cutting time were presumed to be one hour, and the setting and handling time were two minutes, it would be possible for one man to look after 30 machines, the limiting factor as to the number of machines which can be worked on the same part, without loss of time, being the number of machines into, and from which, pieces can be put and removed without exceeding the cutting time of the longest operation.

Yet, so far as economy is concerned, it ought not to be assumed that this is ensured because more than one machine is worked by one man. If wages be considered as constituting the only factor there is no argument, but if individual machine output be the criterion it may be found that much of the apparent economy is dissipated. The number of machines referred to in the hypothetical case taken may be considered as covering too large an area to allow of their being suitably overlooked by one man. 6 machines, however, have been frequently and efficiently kept running by one man and, for purposes of illustrating the point in view, 6 machines will be presumed to be set up for the milling of different operations on the same piece. The operations are likely to differ as to the amount of work involved in each, and this difference will be reflected in the cutting time. The setting time on each machine will be taken as identical, namely, 1 minute. Then the cutting time on the longest machine must be equal to or greater than the combined setting times for the operations on each of the 6 machines less one, and this, without any allowance for contingencies, and treating the worker as being an automaton, will be 5 minutes.

The length of time—cutting and setting—for each of the six operations is taken as follows :

	Time in Minutes.		
	Setting.	Cutting.	Total.
Machine No. 1. -	1	4	5
,, ,, 2. -	1	3½	4½
,, ,, 3. -	1	5	6
,, ,, 4. -	1	5	6
,, ,, 5. -	1	4	5
,, ,, 6. -	1	2½	3½
Grand Totals -	6	24	30

The total output is controlled by the longest operation and the value, in terms of time, of the output obtained from the 6 machines will be seen to be 30 minutes, as against 36 minutes actually spent, or, taken per machine, the average time value of the output given per machine is 5 minutes against an expenditure of 6 minutes. Thus, when making the best of the conditions, there would be an average loss of 20 per cent. of the machine time taken when compared with that effectively used.

If the assumption be taken a stage further and the loss of time which is inevitable, if only because the worker is not an automaton, be allowed for, and it is considered that the actual daily output is less than that theoretically possible by 16.6 per cent.—this figure is not excessive—the position is made worse accordingly as the number of machines worked is increased, and for two reasons.

In the first place, the loss of output referred to as being inevitable is assumed to be due to the human factor, but whereas, when 1 machine only is worked, such loss would affect 1 machine only, when 6 machines are worked 6 machines would be affected; still further, although 1 machine may be held up for the changing of cutters or some minor repair, the whole 6 machines could be affected—and would be, excepting the machine concerned were the last in the series, was used for a short operation and was thus capable of being overtaken. Still further, there is the question of two machines requiring attention at the same time—overlapping—a measure of which is unavoidable. Calculating on a total wastage from these causes of 16.6 per cent. the time value of the output would be reduced from 30 minutes to 25 minutes and the machine time actually taken—36 minutes—would be 44 per cent. in excess of that actually used.

Unfortunately the position has not even yet been fully dealt with. In practice, when more than one machine is being worked and the rate of travel is questioned, the reply given by the foreman often is—"True, but the man is running several machines; it can't be expected." This is an example of the loose thinking which has crept in, and the running of several machines is too often accepted as justifying a reduction in the output per machine. It is likely that some reduction in output is unavoidable, but this can have such serious results that it is essential, wherever more than one machine is worked by one man, that all the effective factors should be considered, output, labour cost, and oncost, of which, output is paramount because of its influence on the remaining two.

The object of saving labour cost is a most worthy one, but it must not be allowed to become an end in itself, or the most unexpected results may be achieved. In the hypothetical case taken—it is based on experience—while the labour cost per piece was undoubtedly reduced, the resultant total cost, allowing for the incidence of oncosts at an hourly rate for the machine, was, at the time and oncosts rates obtaining, in excess of that shewn when one machine only had been worked. As the oncost rate is greater than the time rate, this feature is the more pronounced.

It cannot be too strongly emphasized that efficiency per machine is as essential, when several machines are worked by one man, as where one machine only is concerned, and that, without this be assured, the position is one for investigation.

In the illustration taken, obviously the first consideration would be to see to what extent the difference between the times of the "long" and "short" operations could be decreased, either by the use of faster feeds or by arranging for the shortest two operations to be done on one machine.

It is in the estimating of the rate of production that the facts should be ascertained, and the methods and the rates of cutting

used in the calculation of the rates of production possible, should be the same as though there were but one machine in use. Treated thus, the economies possible, and they are real, would be made clear.

When time has been estimated and the relation of cutting and handling time to each other can be known, the use of the formula given below will enable the maximum number of machines to be known, which can be attended to efficiently by one man. It is false economy, however, to make a gang of machines too large; to do so is to make an apparent saving in wages and an actual loss in total cost through machines standing idle, owing to the difficulty of keeping each machine constantly running. It is wise to allow a given percentage to cover overlapping when calculating the number of machines to which one man should attend. Setting time being the effective factor, this percentage should be added thereto, not to the cutting time. The number of machines would be obtained as follows:

$$\text{Number of machines} = \frac{\text{cutting time}}{(\text{setting time} + \text{percentage to cover overlapping})}.$$

Then with 4 minutes cutting time and 1 minute for setting, and, say, 16.6 per cent. to cover overlapping,

$$\text{Number of machines} = \frac{4}{(1 + .166)} = 3.4 \text{ machines},$$

say 3 machines.

Where a number of operations on the same piece is involved, the procedure would be somewhat similar. The setting times for all the operations should be added, and this, with its percentage addition to cover overlap, ought to be less than the greatest cutting time. Thus, if the total setting time plus overlap were 6 minutes and the duration of the longest cut were 5 minutes, such a batch of operations could not be economically done on a gang of machines attended to by one man. Idle time would be unavoidable.

It is necessary to consider the relation of output to cost, not from a wages standpoint only but from the more important one, in this case, of oncosts. In those works where oncosts are apportioned on a time basis the importance of the question is likely to be realized, but where, as is so often the case, oncosts are apportioned on the basis of the wages paid, the effect of low output is largely hidden generally, but particularly so where more than one machine is worked. When wages only are considered in this respect output can fall 50 per cent. before loss would be shewn, whereas, excepting the oncosts be less than the wage rate paid, loss would be incurred at a much earlier stage.

Taking, for purposes of illustration, a time rate of 6 pence per hour and an oncost rate of 9 pence per hour—in many works this latter is higher than 1/- per hour—the following figures indicate the output requirements to avoid loss only, 100 being taken, in the case

of the one machine, as the normal output efficiency when one machine only is worked:

No. of Machines Worked.	Hourly Rates in Pence.				Efficiency Required per Machine to Prevent Loss.	Articles Per Hour.		Cost Per Article. Pence.
	Time.	On-cost.	Machine Total.	Gang Total.		Per Machine.	From Gang.	
1	6	9	15	15	100	10	10	$1\frac{1}{2}$
2	3	9	12	24	80	8	16	$1\frac{1}{2}$
3	2	9	11	33	73·3	7·3	22	$1\frac{1}{2}$
4	1.5	9	10.5	42	70	7	28	$1\frac{1}{2}$
5	1.2	9	10.2	51	68	6.8	34	$1\frac{1}{2}$
6	1	9	10	60	66.6	6.6	40	$1\frac{1}{2}$

From these figures it will be clear as to how easily the possibilities of economy can be dissipated, if all the factors are not considered and the importance of efficiency of output is not realized.

It is quite common to find pieces on which there is but one operation of a type to be done, although such operation may be identical with another which forms one of a number required on some other piece, and it has frequently been found that, where there is but one operation to be done on a piece, the arrangements made call for one machine only to be worked. Such an arrangement leads to inconsistency. By the use of the formula given, however, it is possible to treat individual jobs independently, indicating the proportion of the worker's time each separate operation will take up. It is not necessary that the working of more than one machine should be confined to operations affecting the same piece.

The question arises as to how the job rates should be given in such cases as that referred to. In the first place, the job rate must be in accordance with the results made possible and the criterion must be the number of pieces which can be put down as finished for the whole of the operations—for the man-hours involved, not the effective machine-hours; that is, in the example given, the time required must be taken as 6 minutes per piece and not 5 minutes, the average effective time for each of the 6 machines.

To do this the job rates must be based either on the man-hours worked or on the gross machine-hours. This is a matter which has been the cause of some difficulty owing to the fact that, when the machine-hours are booked, these are much in excess of the man-hours worked, while, when the man-hours are booked, the "time taken" must be apportioned amongst the jobs concerned.

The difficulty is more apparent than real, and with suitable provision for the booking of time, can be conveniently overcome; as

a matter of fact, where oncosts are distributed on an hourly basis the provision required should be already in existence.

Consideration of the two methods referred to shews advantages and objections. Dealing with the last mentioned first, the time booking position would be as follows:

For a gang of machines worked by one man, the machine-hours worked are 6 against the man's time of 1 hour. It can be logically argued that the time required per machine is equal, and that, if the man's time be equally divided and apportioned to the jobs being done on the respective machines, correct costing will be assured. That is, if 6 hours are taken, 1 hour would be booked against each job, excepting where all the operations were on the same piece, when obviously no division would be necessary.

While it is true accurate costing would be possible, it is equally true that, for purposes of production statistics, the time so booked would be incorrect, and excepting particulars as to the number of machines worked were entered for convenient reference so that the actual machine time would be available, the record would be one suitable for costing only, being deceptive for any other purpose. Where oncosts are distributed on an hourly basis, of course, such a record would be useless, while their distribution on a basis of percentage on wages spent, in these circumstances, presents an arbitrary division of such a nature that the results could not be other than incorrect.

Considering the same gang of machines worked by 1 man, with the machine time booked, the position can be worked out very differently. Assuming each job to be different and, therefore, that individual booking is required, the actual machine-hours must be booked against each job; then, of course, it would be found that the machine-hours booked would be 6 times as many as the man-hours worked. To deal with this factor, the division and apportionment of the time rate has been found to be the most convenient method, and in so far as thereby no figures are juggled with, and elasticity is assured as well, no serious objections have been found. Thus, if 4 machines are being worked and the time rate is 6 pence per hour, the cost of labour for each machine would be 1½ pence per hour, and the labour cost per piece would be calculated on that basis. Extra pay would be similarly dealt with.

The factor to be used in dividing the rate, however, needs to be set down in a definite form and to be convenient for the reference of the costing department. The decision as to what the appropriate factor must be naturally falls to the production estimator, and it is convenient for the factor to be linked up with the job rate. Then on a job which is classed as a 3 machine job—that is one where the cutting and setting times bear such proportion to each other that two other machines could be worked without loss of output,—the job rate given would be qualified by a symbol which would indicate its class as, for example, 4 minutes each 3♮. Then assuming that 120 pieces had been machined in 6 hours, the total

job rate being 8 hours, 2 hours would be shewn as saved. For costing purposes, the rate of, say, 6 pence per hour would be divisible by 3 according to the factor, and the cost would be taken as 6 hours at 2 pence per hour plus the whole or the proportion of the time saved, appropriate to the system of payment by results in operation, and at the rate of 2 pence per hour; the time rate can be written $\frac{6}{3d}$ if desired.

Apart from the advantage of figures meaning what they represent, the elasticity obtained is worth some consideration. If the principle be definitely recognized that on certain classes of machines and operations more than one machine can be worked efficiently, then, excepting such a number be actually worked and on suitable operations, the labour cost will be higher than needs be, owing to the number of machines worked being too few, or the production per machine may be low owing to more machines being looked after than is physically possible, consistent with the obtainment of efficient results; a flat number of machines per operator is not necessarily the right solution.

To find jobs suitable in themselves for the different machines is not always an easy task for the shop foreman, and if, in addition, there were limitations of time to be considered, always, this would be but to increase the difficulties. On the other hand, if less than the requisite number of machines be worked, the worker concerned may be held to be doing less than a full day's work; further, if he be working more than the requisite number, he is being asked to do more than is recognized as a full day's work, and it is not unreasonable that this should be paid for.

Where the time taken is split up amongst the machines worked, and the job rates are based accordingly, the two methods of time and extra pay calculations, here discussed, have distinctly different results. Where the time worked is divided and apportioned amongst the various jobs, and the job rates are divided similarly, then, excepting the full number of machines be worked, the worker is not afforded the opportunity to earn the full amount of extra pay, and sometimes none at all, while when, machine hours are booked and the job rates are given accordingly, opportunities for earning extra pay are afforded if one machine only is worked, although in that proportion only which one machine bears to the number which should be worked. Then, if the worker were attending to 1 machine only and 6 was the requisite number, he would be able to earn one sixth only of his normal extra pay. It is all a question of point of view and aims.

Thus if 6 machines be considered as constituting a gang, and the time rate of the man working them be taken as 6 pence per hour, that is equivalent to each machine costing for labour, 1 penny per hour to run; if a system of payment by results be worked and 33⅓ per cent. extra pay be allowed for and earned, the earnings per machine, per hour, would be 1⅓ pence, while the total earnings

of the worker would be 8 pence per hour. If, further, the output from each machine be assumed to be 10 pieces per hour, the job rate per piece, if given in terms of money, would be .133 pence each. Then comparing the results under the two systems discussed extra pay would be earned under the plain premium system as shewn below.

TIME RATE 6d. PER HOUR.		DIVIDING TIME WORKED.			DIVIDING TIME RATE.			
Machines Worked.	Pieces Produced per Hour.	Job Rates in Pence. Each.	Job Rates in Pence. Total.	Extra Pay Pence.	Job Rates in Minutes. Each.	Job Rates in Minutes. Total.	Machine Minutes Taken.	Extra Pay at ⅛ Time Rate Pence.
6	60	.133	8	2	8	480	360	2
5	50	.133	6.6	.66	8	400	300	1.66
4	40	.133	5.3	—	8	320	240	1.33
3	30	.133	4	—	8	240	180	1.
2	20	.133	2.6	—	8	160	120	.66
1	10	.133	1.3	—	8	80	60	.33

If the policy be decided from the standpoint of money payments only, the system of splitting the time rate and of giving each job an independent job rate, thereby providing continued opportunities for earning extra pay even if the extreme case of working one machine were reached, would stand condemned; but, if the question of output be considered as having the greater importance then, all things considered, not the least of which is oncost, this method will be found, most probably, to be the more profitable.

In the first place, of course, it is up to the shop management to provide full employment, because with time rates guaranteed, anything less than full employment means additional cost, and in this case full employment means working the requisite number of machines. But, if a sufficient number of jobs are not always available to enable this to be done, what course is to be followed? If opportunities for earning extra pay are entirely withdrawn, the output from the remaining machines will be likely to fall; on the other hand, where the opportunities for earning extra pay, per machine, remain the same, the production per machine per hour is more likely to be maintained at an efficient level although the production per man-hour will have fallen. It should be borne in mind that on the production of the machines which are in use falls that portion of the standing oncosts which would ordinarily be apportioned over the production from the machines which may be standing.

The position may be thought to be comparatively unimportant, but a considerable amount of slackness exists in connection with the whole question. It is by no means uncommon under the

" divided time " method, when less than the requisite number of machines are being worked, for the normal earnings to be made up, either by special job rates or by an arbitrary addition. The true position is not sufficiently appreciated; quite often it will be found that the attitude adopted is that the worker is conferring a favour upon his employer if he consents to put pieces in and out of 4 machines instead of 1, and that, should jobs be available for 2 machines only, the opportunities for continuing the conferment of that favour have been withdrawn and the worker continues to carry out a normal task.

While the latter view is wrong in principle, there is at the same time another aspect of the question which deserves notice. The neglect as to the importance of the number of machines which can reasonably be worked can shew up in more than one way, and it may be found that some worker is working a number of machines greater than that laid down as being suitable. Remembering that the object underlying payment by results is to induce the best output, and that on repetition machines, in particular, once feeds and speeds have been decided upon, the maximum output can be definitely calculated, to exceed which the worker should find it difficult to go, it is quite desirable to take advantage of and to remunerate any specially energetic worker who, by taking advantage of the overlapping allowance, is willing to work an extra machine and is able to do so efficiently, and the inducement so to do should always be in evidence. Under either of the two methods discussed this can be done, although, if the additional machines so worked were allowed to affect the division factor for either the time taken or the time rate, then, excepting some addition were made to the job rates, no opportunity would be afforded for earning increased extra pay.

Under the circumstances, the best plan is for the ordinary job rates to stand and for the usual routine to apply. Then, should a worker be able to keep five machines running efficiently on jobs for which four machines were considered to constitute a fair task, he would be given the additional extra pay earned thereon, the machine symbol not being altered.

To what extent modification should be made or which of the methods should be adopted is a matter for local decision, but in making that decision, it should be borne in mind that in providing sufficient jobs for the requisite number of machines to be worked, opportunities only are provided, and this provision is under the control of the manufacturer; while in the working of additional machines, bearing in mind that it is the man of average ability who is catered for, the inducement must be sufficient to justify the workers' consideration.

Treating each job as an independent unit, however, and indicating the number of machines of which it can efficiently form one, the information can be passed on to the shop foreman and be used by him to help man his machines efficiently.

Thus jobs may be marked 1♮, 2♮, 3♮, 4♮, etc., and the number quoted, in indicating the number of machines which can be attended to, would also indicate what proportion of the man's time the working of a machine on that job would be required ; 2♮ indicating one half, 4♮ one quarter, and so on. Then if a man had been working four machines on operations of equal value and two of these were running out, the foreman would know that a 2♮ job or 3-6♮ jobs would maintain the balance.

In cases where fixings are not well designed, or where very intricate pieces are concerned and the setting time is likely to be unusually long, it may be found necessary, where single operations of this kind are concerned, to fix as a basis of comparison with cutting time, a maximum setting time. For example, two operations may each be classed as 2♮ operations when the setting and cutting times were 1 and 2 minutes and 3 and 5 minutes respectively. Obviously, to link up together, as 2♮ operations, two jobs, the setting time of one of which was 3 minutes longer than the cutting time of the other—2 minutes, would be to ensure loss of output, the additional cost being borne by the part which was not the cause. The maximum setting time should not exceed the minimum cutting time.

Reverting to the cost and extra pay calculations, the work card for each job finished, being independent so far as job rate and time booking are concerned, can be completed and cleared up. Should the number of machines actually worked be different, more or less than the number specified or indicated by the job rate, then, dependent upon the costing policy, adjustments would require to be made to the factor to be used when splitting the rate, or the factor specified would be retained and the difference in actual cost debited or credited to the departmental oncosts, a report being made to the works manager accordingly, so that enquiry or acknowledgment could be made as thought advisable. There is an advantage to be gained in following the latter course because, in so doing, an account could be kept of all the expenditure made in this manner, the influence of which, on the shop supervision, would be most valuable, and would be a real inducement to the efficient running of machines when grouped in this manner.

CHAPTER XXII

TIME-BOOKING AND EXTRA PAY

AFTER the worker has been notified of his job rate and the same has been agreeably fixed, there remains the question of the calculation and payment of the extra pay which may be earned. This involves a record of the time worked, a description of, or some recognized reference to, the operation performed, particulars of the number of pieces done, and of the results of inspection as regards the number of pieces accepted, returned for rectification, or scrapped.

These are the minimum requirements in order to enable the extra pay earned to be calculated and paid. Instances have been known where nothing further has been provided for, payments being made without any check as to the accuracy of the time booked, without being charged to any works order number or being linked up to the job cost in any form other than generally through the oncosts. The folly of this is so obvious as to render discussion unnecessary, but the importance of the records being efficiently made can hardly be over-emphasized, because of their relation to cost, the need for the accuracy of which is being increasingly recognized.

Extra pay is clearly a part of the direct cost of production and its linking up with the ordinary cost accounts needs to be satisfactorily done. In some works the necessary calculations are worked out in the rate-fixing department, particulars being passed on to the cost department in the form of amounts to be paid. From several standpoints, two of which are worthy of mention, the practice is unsound: One is, that a cost or timekeeping department will be in existence with a staff capable of and used to handling such calculations; to do the work in the rate-fixing department means duplication of staff, which is costly, while the transference of information often causes error. The second is, that where wages calculations are involved—and extra pay calculations are of this nature—it is safer to arrange that the departments responsible for the basis of the calculations should not be responsible also for the making of the calculations themselves; the human factor enters into the question, and the experiences of a number of firms in this respect are unhappy.

It is a convenient arrangement for the rate-fixing department to be responsible for fixing the job rates and also for the making out of the job cards—using card writers for this purpose. In those cases where the job cards are made out by foremen, the responsibility for ensuring the accuracy of the information as regards job rates, which indirectly involves the description of the operation, would still be that of the rate-fixing department. At this stage, however, their responsibility should cease and this should be taken over by the timekeeping department.

In addition to the information required to enable extra pay to be calculated and paid, order number and, in the cases of big units, the section number of the piece are required for costing purposes as well as the items previously mentioned, while for purposes of record and for future reference, the machine type and number and the form of the material used should also be indicated. The starting and finishing times and times of interruption should be recorded and, also, the hours worked per job daily. These should be checked with the total hours worked as shewn by the attendance record of clock or check and the two should balance.

To fail in any one of these directions is to take an unnecessary risk. The need for accurate detailed costs requires no emphasis. Where records are concerned, firms have been safeguarded against serious charges of cutting job rates, solely because their job cards have contained sufficient information to support the action taken, thus enabling the case to be proved. From another standpoint, failure to ensure the accurate booking of time not only results in inaccurate costs but directly encourages dishonesty, and incidents such as the following will be likely to take place.

A piece-work system was in operation in a works of no mean dimensions; the job rates were given by the foreman; the time was recorded on job cards, every care being taken to prevent, as far as was possible, any "cooking" being done. Card clocks were provided and the pieces were batched in prearranged quantities; each batch of work was inspected before any extra pay was calculated, and the calculations were based on the numbers passed as good. The timekeeping department, however, failed to check the hours "worked," as shewn by job cards, with those recorded on the time cards on entering the works, and fraud of two kinds was encouraged.

Men were found to book both more and less time than that actually worked, and investigation shewed that men working 45 hours had been booking as many as 80 hours per week on job cards. With the connivance of a dishonest viewer and the carelessness of the sectional foreman, jobs had been booked through as done which had never been seen, and the men concerned had been drawing, on 45 hours worked, piece-work balances on the basis of 80 hours supposed to have been worked to the value of time and a half—40 hours.

On the other hand, less hours should not be accepted, for similar

reasons. On another job 10 hours had been worked, but 8 hours only were booked. The job rate was equal to 12 hours time wages, and the records indicated that time and a half had been earned. It was common, however, to find that there were differences between the hours worked as shewn by the time records and those worked as shewn by the job cards, these differences being sometimes as high as 30 per cent. Thus, while on paper, as a consequence of this short booking, the cost would shew as 12/- per article, the true cost was 10 + 2 + 2 hours, that is 12/- job rate paid for 8 hours booked plus 2 hours time wages at 1/- per hour not booked to any job—14/- in all, an excess over the job rate of 16.6 per cent.

The accurate booking of the time offers no real difficulty. Many elaborate systems are in use in this connection, but it is questionable if all of these justify themselves. Much is argued for the accuracy of costs based on clocked records, but after all, as far as true accuracy is concerned, the clock serves no further purpose than to record the time at which it was used; where job cards are "clocked" the records are made in such a manner that alteration is difficult, but nothing further is assured. The man who is out to falsify his bookings can do so, whatever system is in use. If a job be finished at 10 a.m. and the worker has "rung off" at 9 a.m., the use of the clock does not show this and, excepting the job actually worked upon between those hours be examined at the time and compared with the job "in hand" as shewn by the job card, such fraud is not likely to be found out.

An advantage of the clocked record, in such a case, is that the fraud would be apparent, the record having to be made at the time, whereas, when the records are written and made by the worker, such fraud is made easy, because it is not necessary for the record to be made at the precise time. Then, if the job worked upon did not tally with the job "in hand" card records, the worker could say he had forgotten to fill in the time or he was in a hurry to get the new job under way, plausible and, possibly, correct statements.

Really the best safeguard in this respect is for the foreman, who gives the instructions as to the next job, to fill in himself and initial the starting and completion time of each job; the question of writing or "clocking" the records then becomes a matter of minor importance.

The booking of quantities is often a matter of considerable difficulty, such difficulty being increased as the quantities handled are large and as batching is not done, although batching itself is no real safeguard; a record must be made of the various operations performed and the numbers passed for each batch. If an order be issued to the shops for the manufacture of 10,000 articles, then, whether they be batched or not, excepting they are done in one large batch and counted accordingly, in the absence of an operation record of the quantities worked upon, no knowledge exists as to whether more or less than the authorized number have been booked through.

In one works batching had been carried out and records of the batches done for the different operations were made, as a result of which it was known that those quantities only which were passed were paid for. Batching, under new management, however, was dispensed with as unnecessary. After a year's working under the "new" old methods, it was decided to investigate one order to see whether the quantities booked, passed, and paid for were correct.

The results were somewhat interesting. It was found that on an order for 100 large pieces, the numbers "done" on the different operations varied from 100 to 112. In some cases the inspector's signature had been forged, while in others the cards were apparently in order. The surplus cards were generally for operations with big job rates. The supposed elasticity which went with the stoppage of batching proved to be a costly improvement, and it was found necessary afterwards to give each large piece a number, painted on, to batch them in fact, and to issue a job card for each operation, either for single pieces or for several together, on which were quoted the numbers of the pieces which were to be worked upon. Inspectors were instructed to write the numbers passed in words, not figures, and general instructions were issued to all that no cards but those specially written were to be accepted and that no alterations to these were to be made or passed. The fraud was stopped by these steps being taken, but the points of importance are that changes which are apparently economical do not always prove to be really so, and that fraud of this kind cannot take place, excepting the cost figures are affected also. If 12 articles are booked in where 10 only have been done the cost figures are made to appear 16.6 per cent. lower than they actually are.

Because of the unsatisfactory booking of time, operations and quantities, grave difficulties are experienced in many works in respect to the preparation of detailed costs, and the statements which are put up to boards of directors are too often half fact, half estimate and, in some cases, are entirely "jumped" or guessed.

Inspection. The results of inspection need to be linked up with the operations done and the time booked. The job rate given applies to work which is done within a fixed standard of accuracy and finish, and payment should not be made until the reaching of this standard and, also, the quantity done, have been verified. In some cases it is found that, although the standard has not been reached, it is possible to rectify some of the rejected pieces so that they can be brought within the standard laid down.

This rectification is a troublesome matter at times, because it is not always possible or desirable to hold up the remainder of a batch—the parts that are correctly finished—while the faulty pieces are being corrected; on the other hand it is not always convenient for the rectification to be put in hand at once. When the latter is possible, particularly in those instances where the rectification requires the same process as the original operation, no difficulty

should be experienced, and the man who did the work badly should, if possible, be given the work of rectification to do, his time for so doing to be booked on the original job card to be counted against the job rate.

It is where the rectification required cannot be carried out by the same process that difficulties are met with, as with automatic machine and some capstan work or where too much material has been left on faces to be removed by fitters; where distortion has taken place as a result of bad clamping; these and similar operations can cause delay both in preventing the good work from being passed along and in the payment of the extra pay otherwise due. In this connection, it is worthy of consideration as to whether the amount of time required to carry out the rectification can be estimated and a job rate made for same, its amount to be deducted from the total original job rate. This would make it possible for the good pieces to be passed along for further operations and for the job card to be sent through for payment. If this be done, it will be necessary for the card issued for the rectification to be linked up with the original so that the total cost can be obtained. This can be done by quoting the number of the original card in the rectification instruction and on the rectification card.

It is important that any deductions so made should be allowed in their entirety to the workers who are called upon to make the rectification, otherwise such deductions would be quite unfair and would give rise to discontent.

Work which is spoilt through faulty workmanship is easily dealt with, no payment being due for any work done. The infliction of a penalty for work carelessly spoilt is a matter for the management, or if payment for the damage is required, this must be dealt with as laid down by law.

It follows that some suitable means are required to enable these various records to be collected in a convenient form so that the calculations necessary can be readily made; it is also necessary to provide a convenient method of filing for purposes of reference. Whether the form used be printed on thick or thin paper is not of great importance; in some measure this will depend upon whether the record of time worked is made in a clock or by hand, but the form itself can be made so that it will present a complete record of the happenings in connection with the carrying out of a particular operation.

For purpose of illustration, a facsimile of a job card designed to meet these requirements is given on pages 232 and 233. Provision is made for three distinct sets of conditions. In the one case, clocks are used, in the other two, the records are written. The plain and sharing premium systems were in use, the job rates being given, in different departments, both in terms of time and money. The cards are provided with a counterfoil, perforated for easy removal, on which are repeated the main heads so that these filled in enable the counterfoil to be used for progress purposes,

intimating that a given job has been commenced; the counterfoil can also be used as a check in the case of illegal alterations to starting time, job rate or quantities, and in case the card gets lost. By filing the counterfoils in numerical order under " cards received" and " cards not received," it is possible to see what cards are outstanding and for how long. In the event of cards being destroyed in the shops this is often a useful means of detection.

The abbreviation above " R. F. Signature " on the counterfoil, "est."—for estimate—will be noted. The reason for this is that the rate-fixer, in being called upon to write down the estimated time on the counterfoil as well as the job rate on the card, is less likely to make an error when both items have to be looked up. This is especially the case when apprentices' job rates are concerned, a check for clerical accuracy being possible without reference to the rate-fixer.

In the top right-hand corner the order and section numbers are called for, while on the opposite side the part or drawing number of the piece worked upon is entered. The card number being also printed at the top of the card, the references which are likely to be quoted when a card is enquired for are all in convenient places for being readily found when filed.

On the reverse side the card is so ruled that, if used in the clock, the lines are in the right position. The foreman makes or confirms the entry, his signature being the authorization for its acceptance. Lower down provision is made for a daily record of the time spent on the job, whether one or more men are concerned. These cards form a convenient method of booking the time for cost purposes and for checking against the time attended and, if kept in a card rack, enable the timekeeper to do his work at the rack with a minimum of time and trouble.

It is possible, of course, to print this information the other way round so that it can be read and filed in an upright position. This is a matter of choice, there being no great advantage in either method. Cards can be arranged so that provision is made for instructions to be given as to where the pieces are to be sent to when inspected, such as the next operation or to store. This method has its uses, particularly when the product is a new one, but of course this is possible only when operations are predetermined. Where clocks are not used, there is less restriction on the size of card which can be used, and with a larger card additional information can be provided for if desired. It is wise, however, to remember that the more information asked for, the more complicated must the card become and the more the chances of error. Many variations are possible according to the requirements, but so long as space is provided for the essential information, the actual order can safely be left to the individual responsible for designing the card.

The payment of the extra pay earned should be made regularly and as soon as possible after the work has been completed. In some works, so important is the need for this viewed, that payment

Card No ....

Dept. Ref. ....

Order and Section No. ....

Part No. ....

Batch No. ....

No. off ....

Oper. No. ....

Est. ....

Machine No. ....

Starting Time. ....

R. F. Signature. ....

Date. ....

Men's Nos.	Noted Progress Dept.
....	....
....	....
....	....
....	....

Form No. 73.

MACHINEMEN. DEPT. REF. ......

W.E. (U. R. READY & CO.) Card No. ....

Part No.	NAME OF PART.	Batch No.	No. Off.	Order & Sect. Nos.

DESCRIPTION OF WORK TO BE DONE.	Operation No.	Material.	Job Rate.	R.F. Signature.
		Bar. Forging. Stamping. Casting.		
		Machine No.	Allowance and Reason. .... R.F. Sig.	

This Side Out.

Inspection Results.	Men's Nos.	NAMES.	Total Job Rate.	Actual Hours.	Extra Pay.	Time Rates.	Cost.
To be Rectified.							
Man Scrap.							
Material Scrap.							
No. Passed							

By .... | Foreman's Signature certifies Job is ready for Inspection. | Foreman's Signature. | Total Cost.

Date..... .... | Only Parts Passed as Good will be Paid for. | .... | Cost Each.

When Job is interrupted, Time and Date must be signed for by Foreman, such signature authorising the issue of a New Card.

Men's Nos.	ON.		OFF.		Hours on Job.	
	Time.	Date.	Time.	Date.	Foreman's Initials.	

WHEN STAMPING IS DOWN TO THIS LINE, & JOB NOT FINISHED, CONTINUE ON ANOTHER TICKET

No.	Week Ending	Tues. Over-Time	Daily Record of Hours Spent on Job.							Total for Week.
			Wed.	Thur.	Fri.	Sat.	Sun.	Mon.	Tues.	

Remarks:—

Total

FIG. 16.

is made on all jobs finished by the normal week end, at the same time as the time wages are paid for the same period. Thus if the week ends on Wednesday evening and the pay-day is the following Saturday, the extra pay earned on jobs which are completed on Wednesday is paid on Saturday together with the time wages.

The aim is a praiseworthy one, but it means a tremendous rush for the clerical staff and, in some instances, hurried and sloppy inspection, while it is questionable whether any advantage to the workers, which there may be, is appreciated by them. If the extra pay earned be paid one week late, or even if the closing day on which job cards would be accepted for the next pay were on the Saturday before, the rush for the clerical and inspection staff would be avoided, together with the attendant mistakes.

The Calculation of the Extra Pay. Where the piece-work system is in use, the work entailed is considerably less per person than is the case with the use of the premium systems, of which the Rowan system is the most complicated. For the latter system the slide rule is useful, provided it be a long one, but mechanical aids are now available which tend to reduce the work to a minimum.

After the cards have been rated—the time rate is referred to—the extra pay calculated, and the necessary particulars entered in the time book, the cards should be sent to the rate-fixing department for the purpose of checking the estimate and job rate and comparing the starting times with those stated on the counterfoil and also the number off. The extra pay calculations should also be checked and any errors or unauthorized alteration—that is, alteration not covered by a foreman's signature—found in this check should be reported to the chief rate-fixer and investigated. Afterwards the cards would be ready for costing purposes.

Notification of the Payments Made. A good feature is embodied in the agreement entered into by Messrs. Vickers Ltd. with the Barrow Joint Engineering Trades, in 1917. (See Appendix at end of book.) In Clause 12 of that agreement it is provided, amongst other items, that, when payment of the additional earnings secured is being made, the workers shall be given particulars of the amounts and the jobs on which these have been earned. While the practice has never been extensively followed, the provision is a wise one. Without such information, the workers have no means of knowing how they stand as regards the payment of the money they consider they have earned, and mistrust and discontent often ensue. By workers knowing on what jobs payment is being made and its amount, many queries are avoided, while a feeling of confidence and fair play is encouraged. As far back as 1903, this was the practice of Messrs. J. I. Thornycroft & Co. Ltd., at their Chiswick works, where it was much appreciated by the workmen generally.

CHAPTER XXIII

PRODUCTION ESTIMATING—GENERAL

UNDER the heading of production estimating will be considered the methods by which the time value of operations can be estimated. This work is usually known as rate-fixing, but the term, through misuse, has lost some of its significance. Really the term rate-fixing is usually associated with job rates, and when the term was coined this was its correct reference. The important feature to-day, however, is not the job rate but rather the rate of production on which the job rates are based. The rate-fixer should really be an estimator first, the fixing of the actual job rate being, from this standpoint, a comparatively unimportant part of his duties. The work of production estimating requires practical craftsmen and cannot be satisfactorily carried out by others. Its need is usually associated with payment by results, but it is really necessary where the time system is in use, if there is to be adequate control over rate of output, while it is an essential requirement in the preparation of estimates for tendering purposes.

Production estimating will not ensure efficiency of output, nor necessarily will it indicate what efficiency is; it is a means whereby data, as to what is possible under certain known conditions, can be used for the purpose of estimating the time which will be required in the performance of operations which may not have been done at all. Thus the estimates arrived at will reflect two factors, the practical experience of the production estimator and the accuracy and satisfactory character of the data used.

It is an unfortunate fact that too little opportunity is given for the collection and compilation of satisfactorily tested data, and there is a wide field to be covered which will be of the greatest value to the industry when done. In the work of Taylor and his successors in America much has been done in this respect, but Taylor's experience in the difficulty of obtaining the interest of firms in this matter is the experience in this country to-day, and the consequence is, much of the work done suffers, because of the incompleteness and the unreliability of the data used.

While it will be necessary to deal with each process by itself, there are certain principles which have general application and these can conveniently be dealt with in this chapter. One of the

first steps to be taken is to ascertain what is actually involved in the performance of an operation on a batch of work. It will be found, usually, that time is spent under two heads, preparation and performance. If a machining operation be concerned, some preparation is likely to be necessary, even if it be but the changing of a drill, and, accordingly as the work which is involved by this preparation takes up a large proportion of the total time required in the machining of a batch of work, so does it become the more necessary for that work to be separated and measured.

The broad principle is that the time for work which is necessitated per piece handled should be kept separate from that which is called for per batch handled. If, for example, a batch of screws is to be machined from the bar on a turret lathe, the first step is to obtain the necessary tools; the collets for holding the bar, the tools for turning the diameter and for parting-off, and the dies for cutting the thread. These obtained, the machine can be set for the performance of the operation, after which the actual work of machining can be commenced. Now, theoretically, the machining time per piece will not be affected by the quantity to be done, neither will the preparation time, but as the numbers of pieces in batches vary so will the preparation time become a larger or smaller proportion of the whole.

Thus, if a given screw could be turned in 5 minutes, and 1 hour were required to set the machine for so doing, then, if two batches of screws were called for at different times, whose numbers were 20 and 200 respectively, while, for each batch, the machining time per screw could be 5 minutes, the setting time, if distributed over the screws in each batch, would be 3 minutes each in the one case and .3 minutes only in the other—an appreciable difference.

While this factor is generally recognized, it is provided for in different ways. In some instances, in fact, no notice is taken, the argument being that, if the quantities are large, the setting time becomes a negligible amount while, if the quantities are small, the workers must share the disadvantage of small quantities with the firm. This practice is not to be recommended; it is not in keeping with the spirit of payment by results and, when the quantities are small, tends to defeat the object in view. In other cases the preparation of the machines is done as a time job. This method is open to much abuse, the wrong booking of time, with the object of obtaining a greater amount of extra pay, being somewhat common. Still further, in some works the job rates per piece are varied in accordance with the size of the batch, the smaller the batch the larger the job rate per piece. By this method the effect of the difference of the numbers in the batches can be counterbalanced, but there is the objection that job rates are not kept constant.

The safer and, it is held, the more satisfactory plan is to treat the work of preparation and performance as being distinct items, the time allowance for which should always be kept separate, that is, one job rate would be given for the setting of the machine and

another one for the machining of the piece. This enables the job rate in each case to be kept constant and enables also the additional cost of machining small batches to be readily appreciated. It does not follow that the time should be booked separately; where the one man sets the machine and does the work it is better for the two items to be treated as forming one operation, the total job rate to be the addition of those given for setting and machining. Then for 20 articles, the preparation job rate for which was 1 hour and the machining job rate 6 minutes each, the total job rate would be 1 hour plus 20 times 6 minutes—3 hours in all.

The next step is to ascertain what is the actual work which is entailed in the preparation of the machine and, further, in the performance of the operation, and to do this efficiently each item must be analyzed into its details so that the respective time values can be estimated. Each separate detail requires to be known for this purpose; each cut to be taken, each size to be machined, each tool or gauge used; the number of times handled, and so on; each is of importance in the building up of an accurate estimate. By this analysis the problem becomes simplified, and consideration can be given to the time value of separated details instead of a conglomerate whole. This analysis is one of the most valuable features of production estimating, because by it attention is confined to essentials, and time can be allowed for those items only without which an operation could not be completed.

The Valuation of Details. The fixing of a time value for the respective details is perhaps the most important in connection with production estimating. However carefully the details of an operation may be analyzed, excepting the time value of these be accurately estimated, the advantage of a correct analysis can be easily frittered away. Questions of cutting speed, depth of cut, and feeds per inch, are of the utmost importance in connection with each of the processes in use, and there is much work to be done in the compilation of that information which is necessary to enable efficiency to be achieved. In addition to this the gauging, setting, and general handling of the job have to be considered, time for every item of which must be allowed.

By cutting speed is meant the rate at which the cutting tool passes over the material. It is usual to refer to cutting as being done at the rate of x feet per minute, and all the references to cutting speed in this book are made in this manner.

In estimating, there are two distinct courses open as to the treatment of cutting speed. A standard cutting speed having been laid down as being the most efficient for the materials being cut, the ideal will be to use that speed, but the different makes of machines in general use, with the varying rates of speed progression and the influence of different diameters or lengths of stroke make the obtainment of this ideal, in close detail, an almost impossible proposition; certainly an impracticable one. Even, however, if it were not impracticable, it would mean that many different job rates would

be required for each operation, and this would be likely to lead to endless confusion and probably to some discontent. The safest and most used plan, where a range of speeds is provided, is to drive the countershaft at such a rate that the range given will be the most suitable for the type of machine and the work to be done, and to leave the adjustment of speed, depth of cut, and feed to the worker and his foreman, or, it may be, for further instruction.

It will save much time if the production estimator keeps in a convenient position two speed tables as shewn on pages 239 and 268, which indicate for various cutting speeds:

Table No. 1. Revolutions per minute.

„ No. 5. Strokes per minute for shaping and slotting machines.

It is desirable also that the speeds actually in use on the various machines shall be known and recorded. These should be checked for suitability when the machine is fixed in the first place, but, excepting a record is called for, the checking of speeds is not likely to be done with certainty, and it is sometimes the custom, for purposes of economy, for machines to be fixed in position and "a pulley" put on to drive. A check of speeds is particularly necessary where two-speed countershafts are supplied.

The author has examined the speeds of machines in a number of works and has found numerous discrepancies. In one instance, in a new works, some hundreds of machines had been installed. These had been purchased from different makers whose ideas of speed requirements varied, and further, in many instances the driving pulleys used had been the nearest available. The results were most unsatisfactory; large machines were running too fast, while small machines were running much too slow. On the other hand, where 16 speeds were nominally in existence not more than 12 were really available, owing to the wrong sizes of pulleys being used causing overlapping, the range of the speeds being restricted at the same time. Added to this, there was the variation of speed ratios commonly found with the machines of different makers.

In counting the speeds of machines it is desirable that the count should be made when an average power load is being carried, although even then considerable variations can often be met with, and it is advisable to compare the result of the count with the calculated speeds and, where there is a substantial difference, to recount the actual revolutions. The speeds of the line shaft or of the motors often fluctuate considerably, and the discovery that this is the case should be reported to the right department, so that the requisite attention may be given. Variations in speed ranging from 10 per cent. to 30 per cent. have been disclosed through the counting of machine revolutions.

A useful check is to ascertain the ratio of the various speeds, either by working from the maker's catalogues or by counting two adjacent speeds on the machines themselves. Speeds are usually designed to advance in geometrical progression, and if the

TABLE OF CUTTING SPEEDS. (No. 1)

Feet per Minute.	15	20	25	30	35	40	45	50	60	70	80	90	100	110	120	130	140	150	
Dia. in Inches.	REVOLUTIONS PER MINUTE.																		Dia. in Inches.
1/16	917	1222	1528	1833	2139	2445	2750	3056	3667	4278	4889	5500	6112	6723	7334	7945	8556	9167	1/16
1/8	459	611	764	917	1070	1222	1375	1528	1833	2139	2445	2750	3056	3361	3667	3973	4278	4584	1/8
3/16	306	407	509	611	713	815	917	1019	1222	1426	1630	1833	2037	2241	2445	2648	2852	3056	3/16
1/4	229	306	382	458	535	611	688	764	917	1070	1222	1375	1528	1681	1833	1986	2139	2292	1/4
5/16	183	244	306	367	428	489	550	611	733	856	978	1100	1222	1345	1467	1589	1711	1833	5/16
3/8	153	204	255	306	357	407	458	509	611	713	815	917	1019	1120	1222	1324	1426	1528	3/8
7/16	131	175	218	262	306	349	393	437	524	611	698	786	873	960	1048	1135	1222	1310	7/16
1/2	115	153	191	229	267	306	344	382	458	535	611	688	764	840	917	993	1070	1146	1/2
5/8	91.7	122	153	183	214	244	275	306	367	428	489	550	611	672	733	795	856	917	5/8
3/4	76.4	102	127	153	178	204	229	255	306	357	407	458	509	560	611	662	713	764	3/4
7/8	65.5	87.3	109	131	153	175	196	218	262	306	349	393	437	480	524	568	611	655	7/8
1	57.3	76.4	95.5	115	134	153	172	191	229	267	306	344	382	420	458	497	535	573	1
1 1/8	50.9	67.9	84.9	102	119	136	153	170	204	238	272	306	340	373	407	441	475	509	1 1/8
1 1/4	45.8	61.1	76.4	91.7	107	122	138	153	183	214	244	275	306	336	367	397	428	458	1 1/4
1 3/8	41.7	55.6	69.4	83.3	97.2	111	125	139	167	194	222	250	278	306	333	361	389	417	1 3/8
1 1/2	38.2	50.9	63.7	76.4	89.1	102	115	127	153	178	204	229	255	280	306	331	357	382	1 1/2
1 5/8	35.3	47.0	58.8	70.5	82.3	94.0	106	118	141	165	188	212	235	259	282	306	329	353	1 5/8
1 3/4	32.7	43.7	54.6	65.5	76.4	87.3	98.2	109	131	153	175	196	218	240	262	284	306	327	1 3/4
1 7/8	30.6	40.7	50.9	61.1	71.3	81.5	91.7	102	122	143	163	183	204	224	244	265	285	306	1 7/8
2	28.6	38.2	47.8	57.3	66.8	76.4	85.9	95.5	115	134	153	172	191	210	229	248	267	286	2
2 1/4	25.5	34.0	42.4	50.9	59.4	67.9	76.4	84.9	102	119	136	153	170	187	204	221	238	255	2 1/4
2 1/2	22.9	30.6	38.2	45.8	53.5	61.1	68.8	76.4	91.7	107	122	138	153	168	183	199	214	229	2 1/2
2 3/4	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.4	83.3	97.2	111	125	139	153	167	181	194	208	2 3/4
3	19.1	25.5	31.8	38.2	44.6	50.9	57.3	63.7	76.4	89.1	102	115	127	140	153	166	178	191	3
3 1/2	16.4	21.8	27.3	32.7	38.2	43.7	49.1	54.6	65.5	76.4	87.3	98.2	109	120	131	142	153	164	3 1/2
4	14.3	19.1	23.9	28.6	33.4	38.2	43.0	47.7	57.3	66.8	76.4	85.9	95.5	105	115	124	134	143	4
4 1/2	12.7	17.0	21.2	25.5	29.7	34.0	38.2	42.4	50.9	59.4	67.9	76.4	84.9	93.4	102	110	119	127	4 1/2
5	11.5	15.3	19.1	22.9	26.7	30.6	34.4	38.2	45.8	53.5	61.1	68.8	76.4	84.0	91.7	99.3	107	115	5
5 1/2	10.4	13.9	17.4	20.8	24.3	27.8	31.3	34.7	41.7	48.6	55.6	62.5	69.4	76.4	83.3	90.3	97.2	104	5 1/2
6	9.55	12.7	15.9	19.1	22.3	25.5	28.6	31.8	38.2	44.6	50.9	57.3	63.7	70.0	76.4	82.8	89.1	95.5	6
7	8.19	10.9	13.6	16.4	19.1	21.8	24.6	27.3	32.7	38.2	43.7	49.1	54.6	60.0	65.5	70.9	76.4	81.9	7
8	7.16	9.55	11.9	14.3	16.7	19.1	21.5	23.9	28.6	33.4	38.2	43.0	47.7	52.5	57.3	62.1	66.8	71.6	8
9	6.37	8.49	10.6	12.7	14.9	17.0	19.1	21.2	25.5	29.7	34.0	38.2	42.4	46.7	50.9	55.2	59.4	63.7	9
10	5.73	7.64	9.55	11.5	13.4	15.3	17.2	19.1	22.9	26.7	30.6	34.4	38.2	42.0	45.8	49.7	53.5	57.3	10
11	5.21	6.94	8.68	10.4	12.2	13.9	15.6	17.4	20.8	24.3	27.8	31.3	34.7	38.2	41.7	45.1	48.6	52.1	11
12	4.77	6.37	7.96	9.55	11.1	12.7	14.3	15.9	19.1	22.3	25.5	28.6	31.8	35.0	38.2	41.4	44.6	47.7	12
13	4.41	5.88	7.35	8.81	10.3	11.8	13.2	14.7	17.6	20.6	23.5	26.4	29.4	32.3	35.3	38.2	41.1	44.1	13
14	4.09	5.46	6.82	8.19	9.55	10.9	12.3	13.6	16.4	19.1	21.8	24.6	27.3	30.0	32.7	35.5	38.2	40.9	14
15	3.82	5.09	6.37	7.64	8.91	10.2	11.5	12.7	15.3	17.8	20.4	22.9	25.5	28.0	30.6	33.1	35.7	38.2	15
16	3.58	4.77	5.97	7.16	8.36	9.55	10.7	11.9	14.3	16.7	19.1	21.5	23.9	26.3	28.6	31.0	33.4	35.8	16
18	3.18	4.24	5.31	6.37	7.43	8.49	9.55	10.6	12.7	14.9	17.0	19.1	21.2	23.3	25.5	27.6	29.7	31.8	18
20	2.86	3.82	4.77	5.73	6.68	7.64	8.59	9.55	11.5	13.4	15.3	17.2	19.1	21.0	22.9	24.8	26.7	28.6	20
25	2.29	3.06	3.82	4.58	5.35	6.11	6.88	7.64	9.17	10.7	12.2	13.8	15.3	16.8	18.3	19.9	21.4	22.9	25
30	1.91	2.55	3.18	3.82	4.46	5.09	5.73	6.37	7.64	8.91	10.2	11.5	12.7	14.0	15.3	16.6	17.8	19.1	30
Feet per Minute.	15	20	25	30	35	40	45	50	60	70	80	90	100	110	120	130	140	150	

higher of two adjacent speeds be divided by the lower, the resultant answer can be used as a factor for obtaining the figures for the remainder.

For example, if a machine is provided with a four-step cone and the steps are referred to as A, B, C, D, then, if the speeds of steps A and B are 100 and 150 revolutions respectively, those of C and D will be proportionately higher, the four being, 100, 150, 225, 337.

It is a useful practice to indicate the speeds of the various machines on a plate of a suitable kind. Added, could be such particulars of the capacity of the machine as the size of job which can be taken, the feeds provided, and the depths of cut which can be taken. This information would be of use alike to worker, foreman, estimator and manager.

Feed and Feeds. The expression feed and feeds is common with all machine processes, although the term feed is most commonly used in connection with milling. Feed usually has reference to the amount of traverse or progression the cutting tool is given across the surface being cut per minute of time, and thus the full expression is feed per minute.

It is usual to refer to feed as x inches per minute, and throughout this book all references to feed are in those terms

Knowledge as to the rate of feed per minute being used can of course be readily obtained by measuring the advance of the table carrying the work, or of the tool across the work in 1 minute of time or, where the machine is run for an extended period, by use of the formula :

$$\text{feed per minute} = \frac{\text{length of traverse}}{\text{time in minutes}}.$$

By length of traverse is meant the distance a tool is taken across the job being machined. Thus with milling, in addition to the rotary motion of the cutter there is a longitudinal motion of the work under the cutter. With lathes, shaping, slotting, grinding, machines, etc., as well as the motion imparted to the tool or the job, either rotary or reciprocating, there is a further motion of the tool across the work. This motion is termed the traverse, and its length should always be referred to in terms of inches.

It is convenient to express rate of milling in inches per minute, because the continuous cutting action of the milling cutter, by virtue of its many cutting edges, destroys the significance of the meaning of feeds per inch ; apart from this, the diameter of the cutter can vary within fairly wide limits without affecting, to any great extent, the efficiency of the cutting done.

The traverse of a single point tool is generally referred to in terms of feeds per inch, and these have reference to the number of times a tool is passed over each inch of surface cut ; thus, if with a shaping machine 180 cutting strokes are required for the

shaping tool to traverse a distance of 6 inches, the feeds per inch will be said to be 30, the formula being:

$$\text{feeds per inch} = \frac{\text{no. of strokes per minute} \times \text{by minutes taken}}{\text{traverse in inches}}.$$

If lathe or drilling machine work be involved, revolutions per minute take the place of strokes per minute. The references to feeds should always be made as x feeds per inch.

With drilling it is convenient and useful to refer to work done as at a penetration of so many inches per minute. At the same time while the measurement of the work done can be made mechanically by means of the rule, analysis of the results can be made only by working back on to feeds and speeds, and any rules laid down as to rates of penetration to be obtained per minute, are less likely to be at fault when these factors are known. Thus, if 100 feeds per inch are used at a speed of 400 revolutions per minute, the rate of penetration will be 4 inches per minute. Such a reference is more easily remembered than the two factors of feed and speed; if, however, when this rate of penetration is being obtained, drills are found to break or "burn," it does not follow that the rate of penetration is too high; it may be that either the feed per revolution is too heavy, the cutting speed being too low, or the speed is too high and the feed per revolution is too low. Hence knowledge of the two factors is necessary.

Removal of Material. In considering the removal of material by cutting, three factors must be borne in mind: (1) the capacity to cut of the tool steel used; (2) the strength of the machine used to utilize that capacity; (3) the rigidity of the job to stand against the maximum of either.

Dealing first with the capacity of the tool steel in use, it must be borne in mind that the removal of material is a complex problem in which there are several variables. While high cutting speeds are desirable, these are effective, only, when the accompanying depths of cut and feeds per inch enable the maximum amount of material to be removed without undue tool wastage. Although every machinist knows that to increase either one of these factors is to obtain different results, the extent of the influence of that change is rarely known, and any rules which exist in workshops regarding cutting capacity relate chiefly to cutting speed only. To know what the cutting speed is, is to be aware of one factor only, and high cutting speeds, when the results of their use are considered from the standpoint of the amount of material removed, often stand condemned.

In some works certain cutting speeds and feeds per inch are specified as being suitable for use on machines of certain sizes. While such a practice has advantages, its application may not be universally satisfactory. Thus, if the speed specified be 50 feet per minute and the feed required be 20 feeds per inch, there will be one depth of cut at which these two will enable the maximum

amount of material to be removed. If it be presumed this depth of cut be .25 of an inch, then, when the amount of material to be removed is .1 of an inch only, the feeds per inch could be increased although not necessarily doubled, while, if there were .375 of an inch to be removed, a reduction in cutting speed of one step of the speed cone or of the feeds per inch may enable the extra depth of cut to be taken in one cut and in less time than as though two cuts were used. It is an advantage, therefore, to consider the amount of material to be removed as well as the use of certain specified speeds or feeds.

Setting of Jobs. The setting of jobs in the right position for cutting, and the consequent clamping, entail somewhat similar considerations for all classes of machining, the exception perhaps being the lathe, on which the rotary motion the machine is given tends to make the setting more difficult, the question of balance being involved. Where the use of the crane is not required the question of time rests entirely with the requirements of the job, and must be decided accordingly, but the need for using the crane may involve, at times, waiting for same to be disengaged. It is easy to make a false step in this respect. It is all too common an experience to find that the organization of the shop crane service is unsatisfactory. The cranes are often held up unnecessarily on assembly jobs, while machines are delayed for much longer periods than those for which the use of the crane is required. The best plan, so far as job rates are concerned, is to allow a fair time for the crane to be brought to the job, for the removal of the finished piece, and for the lifting of the next, any time required above this to be allowed by the shop foreman as "waiting for crane." To attempt to cover even average waiting periods in the job rates is wrong, and goes to encourage slackness in the handling of the cranes. This phase of the question is discussed under "waiting" in Chapter XX. Obviously no standard times for setting can be laid down, as the nature and size of the jobs will vary. The clamping of jobs, when set, will also vary, but when bolts are used the time required will be affected by their size and number, and it is convenient and satisfactory to allow time per bolt accordingly.

Gauging. Wherever work is being finished the need for gauging is encountered. This need is most prominent in connection with fitting operations although, of the machine operations, lathe work, perhaps, presents the most difficult gauging conditions. Excepting some method for considering the amount of gauging really necessary be used, considerable error can be made, the allowances being likely to vary both up and down. It will depend of course upon the accuracy of the work as to whether time is required for gauging at all. If, for example, a small turning job be considered, and a size tolerance of .003 of an inch be given, time for gauging the diameter becomes almost unnecessary, it being possible for all the gauging required to be done while the turning is being proceeded

with, but, when the tolerance is not more than .001 of an inch, the gauging becomes a much bigger proposition.

It is often said in workshops that, with rough work, estimated job rates are more generous than those for finished or accurate work. There is likely to be some truth in this, although not necessarily so much as may appear. Many men can do rough work without difficulty, there being but little difference between the output of one man and another, but, when accurate work is involved, the less skilled man gets into trouble at once. Such a man may be quite successful on rough work, and yet fail on accurate work, but such failure does not necessarily carry with it any reflection on the accuracy of the job rates; the reason may be the man's own lack of skill. There are men who could not bore a jig correctly or cut a satisfactory screw gauge if they took ten times the time normally required, simply because of their lack of skill. This fact requires to be borne in mind when complaints of this kind are made, but time should be allowed in accordance with the size, nature and number of gauges used, never, as is sometimes done, as a percentage of cutting time. That is when job rates for rough work can become more liberal than those for finished work.

Reverting to the time involved in gauging, this will be found to be less with reciprocating machines and, in fact, with the machining of flat faces in general, than with lathe work. In these cases either grinding or hand finishing is usually resorted to, and this of course reduces, to some extent, the need for the closely accurate gauging which would be necessary if the required degree of accuracy were expected direct from the machine.

Even as the more accurate work must involve more time in its performance than the rougher classes, so must more time be allowed, and this may be called for either in the form of extra cuts or higher gauging allowances, most likely both.

Contingencies. If the time necessary for the performance of each detail of an operation were ascertained within the closest possible limits, and the different items totalled, it would be found that the rate of output actually obtained would be less than that foreshadowed by that total, although such deficit would not necessarily signify indolence on the part of the worker. The reasons would not only be various, but their influence would vary with the nature of the work being done. Amongst these reasons may be mentioned:

1. Petty attentions to machine, as oiling, etc.
2. Necessity for more than the normal number of cuts, due to failure of tools, inaccuracy of machine or the faulty manipulation of tools.
3. Attention to tools, resetting, etc.
4. Fatigue or other natural reasons.
5. With assembly work, pieces not being right to gauge necessitating the handling of additional pieces.

The general facts are recognized in most works to-day, and allowances in job rates are made accordingly. It is not un-

common, however, to find that the allowances so made are in the nature of a flat percentage without special reference to the nature of the operation. For example, in one works an addition of 25 per cent. is made to the cutting time ; in another the addition is 20 per cent. to the total observed time taken for the operation. If only because the provision to be made is for possible happenings rather than certainties, a firm estimate is not possible, and the addition of a percentage probably meets the case best, but a flat percentage to cover all classes of work cannot be satisfactory. Differences must exist between classes of work, but the allowances will also vary as between rates of output which are estimated and those which are observed. The reason for this will be readily appreciated if a few examples are considered.

A. A light assembly operation.
B. A heavy fitting operation.
C. A hand operated machine.
D. A power driven machine with hand feed.
E. A power driven machine with mechanical feed—" short " cuts.
F. A power driven machine with mechanical feed—" long " cuts.

With light assembly operations quick movements are required rather than the expenditure of great energy. The worker is more likely to suffer from a kind of " writers' cramp " than from ordinary bodily weariness, and would be relieved more perhaps by a change of operation than by a rest, and a return to the same work. Actually in such work, workers when working alone will, whenever possible, arrange their work so that such a change is assured, while where a group of workers are working together on the same job, and the operations are of a monotonous character, the members of the group will change places for the purpose of counteracting this wearying tendency. In work of this kind, factors 4 and 5 only will operate.

With heavy fitting work, quick movements are not so much in demand as the efficient use of tools, and factors 2 and 4 will be principally in evidence. Hand operated machine work may be comparable to either light or heavy hand work, according to its nature, and the factors operate in a similar manner.

Over against these, mechanically operated machines with hand mechanical feeds bring in another set of conditions. Where the work is light and quick movements are necessary, as with hand fed machines, the influence of factors 1, 3 and 4 will usually be paramount. Work on machines provided with mechanical feeds, but requiring short cuts, will be less wearying than on those provided with hand feed only ; the same factors will operate but will be less felt. Where long cuts are required, factors 1 and 4 become almost negligible, because number 1 can be dealt with when the machine is running, and the importance of number 4 will recede as the machine can be run for long cuts.

Thus is briefly indicated the manner in which the uncertain elements of different classes of work affect the possibilities of output.

The next step is the consideration of the methods whereby the necessary allowances can be most suitably made: it is accordingly as these are satisfactorily arranged that the complaints sometimes voiced that job rates are more liberal on rough than accurate work, will be avoided.

If for the moment an ideal case be considered where no uncertainty exists as to what might happen, where tools do not wear out, and where fatigue is unknown, observation as a means of arriving at the time required to perform an operation would lose any value it now has and rate of output could be estimated with absolute precision, and contingency allowances would be unnecessary, but accordingly as the approach to these conditions is difficult so is the need for these contingency allowances undeniable.

On the other hand, were observation the method used for ascertaining the time value of operations, and if the period of the observation were sufficiently long to cover all possible contingencies, no allowances would be needed because fatigue as well as contingencies would be covered in the time recorded as having been taken. While the latter method is not an impossible one, its use will be found too costly excepting perhaps in connection with operations which are likely to be running for very long periods of time. Observations which are carried out for very short periods of time do not obviate the need for contingency allowances, although the size of the allowance will depend upon the rate of speed of the worker.

This is an important point because it can be found that observations taken of the work done by different workers on a similar operation may shew almost incredibly different results. The author remembers two works, manufacturing precisely the same article, and using similar methods, where, on hand-fed capstan work, the relative outputs were 4 and 12 pieces per minute, and, on fly-press work, 20 and 60 pieces per minute. On the slow rate of movement it is obvious contingency allowances would not be required, while, on the faster ones, 50 per cent. would not be too much.

The shorter the operation and the quicker the movements required, the higher should be the allowances made, and the more profitable will such a policy be found. It must be borne in mind that for a worker to earn double wages, or even more, is not necessarily a reflection on the accuracy of the estimates of production. These must always be based on the capacity of an average worker, and this varies within wide limits; they should not be based as a matter of course on the existing speed of the average worker; this may be quite out of line with the possibilities, and it may be necessary for the rate of movement of a whole department to be quickened up, before a single job rate be given. Where this is the result of production estimating, production estimating may be said to be fulfilling its correct function, which, as stated earlier in the chapter, has a value larger than for the fixing of job rates only.

It will be found to be a somewhat common practice that contingency allowances are confined to the cutting time estimated for those portions of operations which are mechanically controlled, that is, where the work is done by the machine itself. Thus, in a machine operation the contingency allowances would form a percentage of the cutting time, but would be exclusive of the time for setting and handling. Similarly, where hand labour operations are concerned, contingency allowances, generally speaking, are not made, neither is time allowed separately for gauging.

While at first sight this might appear to be illogical it may not be actually so; it depends much upon the circumstances. With machining data, the times estimated are net, but with handwork of any kind, whether in connection with the handling of machines or with bench work, gauging, the uncertain happenings, and the influence of fatigue become embodied in the time observed, and thus do not require to be allowed for again. Alternatively, where no definite data exists and the time allowed is based entirely upon the rate-fixer's ideas as to the time required, no allowance of this kind is required. These are the usual conditions, and go to explain the apparent illogicality of the practice. In those cases where the data used or the observations made are exclusive of these factors—are net as it were—the contingency allowance becomes necessary.

While there is no need to follow any particular form of estimate, there is an advantage in using the same method of arrangement, so that reference to same will be facilitated. Common-sense will indicate the form most suitable, but superficial inspection is rendered more easy when the cutting time and the various handling, gauging, and contingency allowances are kept separate. This renders the analysis of estimates an easy matter, and is in keeping with the spirit which should underlie the whole of the work done. In the sample estimates shewn under the different processes, this practice is observed.

Wherever production estimating is adopted, for the greatest success to be assured, the key-note must be analysis. Whatever may be the nature of the work being done, the operations must be split up into their appropriate details, precisely as the operations themselves are performed, and a time value given for each. It will be obvious that the method is applicable to practically all classes of work, whether it be cutting by machine or by hand; in cloth, wood, or steel; driving nails or keys; sewing or painting; bricklaying or digging; all operations can be analyzed and reduced to such units that some measure of output can be applied which will enable the value of the whole to be appraised. Care, however, is necessary to ensure that the units are the appropriate ones; roughing should not be mixed with finishing, nor gauging with cutting; the calculations must be kept entirely separate. Gauging and setting must always be considered independently of each other, and of cutting; they cannot be treated as having any fixed relationship with each other so that a percentage basis cannot be applied

neither is there any definite connection between them and the size of job, although they may be affected thereby. If these points be given due consideration as they arise, the resultant estimates will be such that, while the existing position as regards rate of production is disclosed, the requirements, for efficiency of production to be achieved, would also be made known.

CHAPTER XXIV

THE TABULATION OF DATA

In the course of time, in each department of every works, there will have been built up a fund of information which embodies the results of experience. Such information may have been the outcome of considerable research and can have been obtained only at great cost ; in some instances it will be found to have been suitably recorded, for the reference of all interested, while in others the record will be found to be mental only, and, consequently, available to none but those whose personal experience is reflected therein, and for no longer a period than their length of service allows. The extent to which this neglect of the use of proved information applies is at times somewhat startling, and, apart from any reference to the subject under discussion, is worthy of enquiry.

Records may have reference to many different subjects, but inasmuch as they have bearing on matters that recur, whether of practice or of performance, individual, mechanical, or material, the tendency is, accordingly as they are used, either to make for economy, for a standard of performance, or to avoid a repetition of difficulties previously experienced and solved. In connection with the work of production estimating and the fixing of job rates this is undoubtedly the case.

The fixing of job rates, like every other function necessary to the running of an industrial concern, should be done efficiently and with economy. In the true sense, efficiency and economy are inseparable, but it is possible to have job rates fixed which, while representing a considerable degree of efficiency, are arrived at by the use of uneconomical methods. On the other hand, rate-fixing can be carried out at a very low cost, and might therefore be deemed to be economically managed although the rates themselves may reflect inefficiency of a disastrous character.

It is an unfortunate truth that the fixing of job rates, so far as its management is concerned, is somewhat neglected, and is frequently found to be inefficiently handled, although it must not be forgotten that rate-fixing, as now understood, is hardly out of its infancy. Nevertheless, the crudity which characterizes some of the work done to-day can hardly be due to the infancy of the

movement, and is, to a considerable degree, the reflection of the indifference—lack of appreciation of its value—with which it is so often treated by management. Beyond providing certain formulae, which in many cases have been thought of by the workers themselves, and a certain amount of data of a more or less incomplete character, the individual rate-fixer is quite often left to his own resources in giving job rates—in spending the firm's money—and does so according to his own particular experience, with its unavoidable accompanying limitations, no check being attempted until long after the event, and then, possibly, because the cost has been shewn to be too high, when of course it is too late.

The ordinary routine of a works often demands, and rightly so, that close attention be given to the question of hourly time rates, these being scrutinized again and again by officials of high standing. The recommendations of foremen for individual advances in time rates are not infrequently turned down as a result of this scrutiny, and, in some cases, not without justification ; but where job rates are concerned this rigid scrutiny is often conspicuous by its absence, and the expenditure of money, in amounts of a far greater value than is the case with time rates, is allowed without check. Practices of a far-reaching character are allowed to grow up in this manner, and these, in their recurring influence, may more than counteract any economy which can result from the well-advised scrutiny of time rates referred to.

It is agreed that absolute control of job rates by rule and formula is not always practicable, if at all. Considerable latitude must of necessity be allowed the rate-fixer on certain classes of work and under certain circumstances; but because this granting of the use of discretion is unavoidable, that is not to say nothing can be done, and such a measure of control or of assistance as is available should be exercised so far as is possible. By some the possibility of doing this is denied, and to the loose thinker or observer a good case can be put up in support, but if job rates are to be fixed on a basis of knowledge of possibilities, then control must be possible, or the scientific fixing of job rates, or of any item going to make up such rates, becomes an impossible proposition, and justifies the description which is sometimes sarcastically applied—guestimating.

Therefore, as a matter of plain logic, the principle must be recognized that, when any calculations can be based on the use of previously ascertained data, some measure of control is possible, and that without the efficient exercise of such control much of the value which should accrue as a result of the use of that data will be in danger of being lost.

One of the main reasons for the contention that the fixing of job rates should be centralized, where possible, under an independent authority is based on the fact that records could be better kept ; that the practices of different departments could be compared and strengthened by action taken as a result of that comparison,

and that consistency of job rates would be more readily assured than would otherwise be the case.

The importance of the influence of the consistency of job rates can easily be undervalued. Even some of the senior officials of a works, as well as the workers, are sceptical of the possibility of "doing jobs on paper," and they are both in the habit of making comparisons more frequently and over a wider area than may be supposed. If it be found that the job rates for similar work vary in different departments, or even with different rate-fixers, some justification is given to their scepticism, and the result is an attitude of uncertainty, if not of contempt, which is difficult to overcome. Consistency of job rates, even if such rates are consistently low, infers some definite basis, an element of reliability not to be affected by a change of personnel, and engenders a feeling of confidence which would probably be turned to satisfaction if the "lowness" of the rates were corrected. Inconsistency reflects a lack of reliable information, and is really inefficiency, and the worker knows it and mentally notes that he is being sought to give efficient results when the knowledge as to what efficient performance really is does not exist.

Every time an estimate is taken out, calculations are required, and calculations take time. If it be known that the tool steel in use is capable of cutting a given class and grade of material at 80 feet per minute and at 24 feeds to the inch, it is worthy of consideration as to whether that calculation can be done once for all time, and the result recorded or the calculations required simplified so that the time element required can be obtained with less effort and also with less risk of error. Take, for example, the time required for drilling. To find the time required to drill a 1 inch diameter hole through a piece of steel 1 inch thick, it is necessary to know the cutting speed, the feed per inch the drill is capable of standing, and the actual distance from the point of the drill to the corner of same, and by the use of the usual formula:

$$\text{cutting time} = \frac{\text{travel} \times \text{feeds per inch}}{\text{revolutions per minute}},$$

obtain the cutting time. If, however, it be known that the cutting speed is 60 feet—229 revolutions per minute, the feeds per inch 77, and the actual travel of the drill be 1.33 inches, then, if that calculation be made once and recorded in a convenient form, it need never be made again, the time required for the actual drilling of such holes being .448 minutes; if, further, the allowances which require to be made to cover contingencies, etc., be added, and similar calculations be made for all diameters and depths likely to be required, and these be suitably tabulated, the drilling practice of the shop concerned would be likely to be kept up at least to that standard; the workers would have confidence that the basis of their job rates was established, while on the other hand the fixing of job rates for that work would be economically done. What is

possible with drilling applies in some measure to most processes, and, provided due care is exercised in the building up of such tables, the influence of their use can be exceedingly stimulating.

The object of tabulation then is to present in a convenient form a record of possibilities as proved from ascertained data. These must not be confused with a record of results, excepting the elements of such results are not only known but known, also, to be satisfactory. At the same time the ensurance of an efficient rate of output is something more than using either the right speed or feed. Thus if, on a capstan lathe, the rate of movement as well as of cutting were slow, the correction of the speed of cutting could be made at once, without affecting the rate of movement, but a table shewing the rate of output possible would shew the need for continued attention, even after the cutting speed had been corrected.

It will be appreciated, probably, that much work is involved in the provision of suitable and reliable tables and of their recognition in practice; it may be that the whole tone of a workshop will have to be improved, and the practices changed, before tabulation is possible, or, if done, before it can be applied with any real chances of success.

A practical illustration of the operation of the working of a factor which has a similar influence to tabulation may be useful.

Some years ago, in a machine shop notorious for its low output, the premium system was introduced, and a shaper found himself very concerned as to the job rates offered him—inconsistency being the charge. "He could make big jobs pay but never small ones." The machine was an exceedingly light one in spite of the fact that it had a 12-inch stroke, and was provided with 4 changes of speed by means of a step cone. It was known that on this machine jobs were rarely done which required the full length of stroke, the majority requiring a stroke of not more than 2½ inches in length. It was also noted that the cone steps giving the faster speeds were dirty as though never used. The speeds, in strokes per minute, ranged as follows: 14, 23, 38, 65. On a 12-inch stroke, on the slowest speed, cutting was done at the rate of 28 feet per minute—this ignores the difference in the speed of cutting and return strokes, while on a 2½-inch stroke, on the top speed, the cutting speed was at the rate of 27 feet per minute. Seeing, however, the second speed provided was the fastest speed in general use, cutting on small jobs was done at the rate of less than 10 feet per minute.

The inconsistency lay with the man's practice. This was pointed out to him, but he contended that he was running so much faster, counting strokes, that his tools would not stand a higher speed. Leaving his machine out of the discussion, he was brought to see that if, when using a 12-inch length of stroke, his tools would stand 14 strokes, which equalled 336 inches per minute, then, on a 2½-inch length of stroke, the tools should be capable of cutting a similar number of inches per minute; further, that if 336 inches were divided by the number of inches in any stroke, cutting and return

being included, the resultant answer would indicate the ideal number of strokes per minute which would be required; in this case 67. This was fully agreed to, and the machine having been tested as to cutting capacity, a factor for cutting was worked out, per square inch of surface covered by the tool, per cut required, and from that day onward no further trouble was experienced. Occasionally, when in doubt, the man would ask, "Is this off the factor?" and on being assured that it was—the proof was invariably offered and refused—the job rate was accepted as correct, and generally proved to be satisfactory. Soon after it was noted that the top two steps of the cone began to shine while the bottom two lost their lustre.

Two objects had been achieved, an increased standard of output and the confidence and contentment of the worker.

To what extent can tabulation be carried out? Is it possible to cover all jobs or must there always be something left to be handled personally by the rate-fixer? Tabulation falls under two heads.

A. Where the form, size and condition of the material can be relied upon within such limits that the work involved will not be affected thereby, and where the form of the material at the beginning of the operation can be foreseen, the job rates can be inclusive of all factors, setting, cutting, gauging, tool handling and contingency allowances.

B. Where the work is of a more general character, and operations rather than complete jobs are considered, where there may be variations as to the amount of material to be removed, and such may affect the amount of work involved, as with scraping by fitters, where the setting of the jobs on the machine may have different values, tabulation cannot be used to cover satisfactorily the time required for whole jobs.

Thus it will be seen that the use of tabulation is restricted to known values. Such values may be variable, if the nature and amount of the variations be known and are consistent, but unknown or uncertain factors cannot be included efficiently. It is possible to build up a table for the shaping of plain faces, but if the time for setting the job on the machine were included, the table could not have general application owing to the fact that two jobs could have surfaces of the same area which required machining, but, while the cutting on each face might be identical in amount, the setting involved might vary considerably; one piece may be set easily in 3 minutes, while another may require 40 minutes. In such a case, tabulation could not be used excepting for the cutting portion of the operation. The decision really lies along the use it is desired to put tables to. It is possible to have tables of all kinds with special application, and where the frequency of their use justifies their provision there is nothing to be said against it; but it is important that their special nature should be made clear, otherwise, with tables in existence having both special and general application, confusion can and does arise.

Among those classes of jobs which lend themselves to special tabulation may be mentioned the drilling of jig held jobs, the reaming of plain holes, the turning and screwing of bolts, the milling of bolt heads, the turning of plain bushes, the shaping and milling of plain blocks, where the size of the material can be relied upon to be consistently supplied, the turning of milling cutters, the milling of teeth in milling cutters and reamers, the turning of plain gauges, the turning and screwing of screw gauges, the making of plain plate gauges, etc., etc.

There are some jobs where complete tabulation is difficult owing to the amount of variation in the references of these, the machining of gear teeth—milling and shaping—being a good example. A table to cover this would require to cater for the following variables: size of pitch; number of teeth; length of tooth; class of material. A table would thus be necessary for every size of pitch and each class of material. In such a case the best plan is to deal with the significant factor which must be permanent, in this case the size of pitch, and, deciding on some suitable unit of value for which the time required would be estimated, reduce the appropriate dimensions on the job to the equivalent unit. Examples of this method will be found in Chapter XXVII.

One case of general application may be cited as an example, a table for vertical milling plain faces. Vertical milling is applied to a large and varied class of work, and while the removal of material is of similar value on many jobs, the setting and gauging may be materially different. A table can be built up giving the times which the removal of the material will take, for different lengths, widths and depths of cut, leaving the unknown or variable items to be dealt with in accordance with the conditions obtaining. The same remarks apply to shaping, the boring of holes, etc. References to tabulation will be found in each of the chapters on production estimating, the general principles only being dealt with here.

One important point to be remembered in connection with tabulation is the necessity to keep records as to the basis used in the building up of the various tables. This is not always done, and in some works no record of any kind exists as to the basis of the tables in use. One of the reasons may be that it is thought the tables made will be proved to be so thoroughly satisfactory that complaints from workers, over job rates based thereon, will not be likely, but this is not the correct view to take. Practices are constantly changing; the cutting steels used are being improved; the materials used in the productions themselves are subject to change, and, excepting adequate records are in existence as to the manner in which the tables were built up, modification must mean the complete re-estimating of same, or a reduction by a percentage which, when handling and cutting have been included, cannot give correct results.

The manner in which tabulation is done is a good index to the efficiency with which the rate-fixing department is managed. Tables

become the basis of the costs of all the work on which they are used, and are so important, because of this, that it would not be out of place if the sanction of the general manager had to be obtained before any tables were put into use. Neglect to ensure that the tables in use have a well-founded basis is a grave reflection on the people concerned.

It is desirable that the basis of tables should reflect good practice, the efficient removal of material and of handling. To this end, the building up of a table for any purpose should be accompanied by a review of general practice; speeds, feeds, gauging allowances, and the time taken in the general handling should be checked. This being done, the whole of the particulars should be recorded together with the estimates subsequently made out. The resultant table should be given a number, and the whole of the information entered in a book for purposes of reference. In the case of changes of any kind being required, alterations could then be dealt with with despatch and accuracy. This book should be available for the information of any estimator in connection with the fixing of job rates, and should also form the text-book for the new estimators taken into the department.

Reference has been made to the fact that when cutting and handling are included in the table, reduction by a percentage is not possible if accuracy is desired. This can be readily explained by a simple illustration. If a table for drilling holes in steel has been built up, and handling were included, and it were desired to use that table for holes to be drilled in brass, then, although the cutting time for brass could be a percentage of that required for steel, the handling, such as shifting from hole to hole, would be the same in each case. If the time per hole in steel were taken as being 1 minute, this time to include a half-minute for cutting and a similar amount for handling, then to allow, say, one half of this time for brass on the score that brass can be drilled at twice the rate of steel would mean that the handling time would be reduced also. This would be quite a mistake, although it is one often made. Where it is desired to use a table for job rates for more than one class of material, it is necessary that cutting time only should be included, excepting in those instances where the contingency allowances are in proportion to the cutting time; then of course these can be included.

Another feature to be remembered is that tabulation should be done always in the same terms. Sometimes tables are built up to represent estimated time—the time in which the work should be done, while again, job rates are quoted and these, according to the system of payment in use, can be from 33⅓ per cent. to 100 per cent. above estimated time. What happens is that job rate times are sometimes mistaken for estimated times, and the appropriate amount being added to same for the system in use, confusion arises at once. When job rates are given in terms of money, and it is desired to tabulate accordingly, this can be done without

danger of misunderstanding, because the meaning of the money rate would be obvious. To what extent the practice of tabulating in money values is wise is an open question, because any change of time rate must mean a change in the job rates, and consequently to the tabulation. At the same time a percentage reduction or increase would be possible in this case.

Attention given on the lines suggested will enable a complete master record of estimated times to be built up in convenient tabulated form, which will preserve the continuity of the practice and methods obtaining, and will make for that most desirable position, efficient and consistent job rates arrived at with economy of cost.

One of the bugbears of tabulation is the amount of calculation involved. If each entry be worked out the number of calculations called for is most voluminous, and this, perhaps, is one of the reasons why slackness has characterized the work. Of course much of the work can be avoided by the use of graphs and, when 3 or 4 points are calculated, fairly close approximations can be obtained. Where a calculating machine is in the works every available use should be made of it, the results often being more satisfactory than when graphs are used. Even when a calculating machine can be used, however, the writing out of the information and the giving of instructions to the operator of same, have to be done, and this often proves to be unsatisfactory. Where the expenditure can be sanctioned, a most useful machine for this purpose is known as " The Muldivo." The advantages of this machine are that its use can be mastered in half an hour, and that, while multiplication and division are exceedingly simply done, repetition adding, of which there is much in tabulation, is done by the mere turning of a handle.

CHAPTER XXV

PRODUCTION ESTIMATING. DRILLING—REAMING—FACING

THE operation of drilling is one of the simplest of the engineering processes, and, perhaps, has been affected less than any other by the great improvements in machine tools and methods which have been made. Machines have been improved, the twist drill has replaced the flat drill in most shops—although the author was interested to find, during the war period, a large machine shop in which these had never been used—high speed steel drills have, to a great extent, displaced those of carbon steel, but the operation of drilling itself remains unchanged.

While the twist drill holds the field, there are certain classes of work where the flat drill has a definite place, and with such operations as countersinking, of which much is called for in the shipbuilding and general constructional industries, some exceedingly quick work is done.

The estimating of rate of output is equally simple, and lends itself to tabulation of a most complete kind, as is common where the size of the tool used controls the amount of work involved. Unlike turning, milling, etc., there is no question of the amount of material to be removed, when drilling from the solid is being done, and this is the more usual condition. The time required becomes a question of depths of hole and the rate of penetration per minute the drill is capable of standing in the respective materials, or of the capacity of the machine. For the larger sizes of drills a considerable number of machines have insufficient power to make the best use of the material of which the drills are made and, consequently, drilling practice, as regards output, varies considerably in different shops and, sometimes, in the same shops on different machines.

The formula for estimating the cutting time is as follows:

$$\text{Cutting time} = \frac{\text{length of travel} \times \text{feeds per inch}}{\text{revolutions per minute}}.$$

Length of travel, in through holes, is equal to the depth of the hole plus the distance from the point of the drill to the "corner"; this distance is equal, approximately, to one third of the drill

diameter. Then the length of travel to drill a hole 2 inches diameter, 3 inches, through, would be 3.66 inches, that is 3 inches, the depth of hole, plus .66 of an inch for the drill point. This allowance will always be necessary in jig drilling; but where holes are being drilled to lines, in which case the drills are usually centred first, that is, the hole is started only, and then " drawn " to the centre as required, it may be found simpler to allow, in the time for centering, sufficient time for sinking the drill to the corner, after which the depth of the hole only should be allowed for in "length of travel." In the case of holes having been opened out with a smaller size drill, the length of travel required to clear the drill point will be proportional; that is to say, if the size of the first hole were 1 inch diameter, and the finished size were 3 inches diameter, the extra length of travel above the actual depth of hole would be equal to one-third of the difference between the two sizes, and in this case would be .66 of an inch. It is important that the influence of the drill point on the length of travel should be allowed for in this manner, otherwise, observations based on the depth of hole drilled, and converted later into feeds in accordance with the speed used, will give an incorrect result. Thus, if a 2-inch hole be drilled through a piece of steel 1 inch thick, the actual length of travel will be 1.66 inches, 66 per cent. greater than the depth of hole, whereas if a hole of the same diameter were drilled through a piece 3 inches thick, the length of travel would not be 3 times that required for the 1 inch thickness—5 inches, but would be 3.66 inches only. The importance of this factor will be more readily appreciated if the inches travel be called minutes, when it will be noted that if the time allowed for the hole, 3 inches through, were 3 times that allowed for one, 1 inch through, this would be 5 minutes instead of 3.66 minutes, or 36 per cent. more than necessary.

The term feeds per inch has been explained in Chapter XXIII. While it is necessary to consider feeds per inch in analyzing performances, once a standard is arrived at, it is often found more convenient to refer to drilling as being done at x inches per minute. The rates of penetration, however, should be arrived at after testing both the speeds and the feeds used, otherwise, if the rate of penetration required be obtained with a feed that is too fine, the cutting speed used must as a matter of course be too high, when the tendency would be to " burn " the corners of the drills; on the other hand, if the speed used be too low, and the specified rate of penetration be obtained, this can be so only when the feed is too coarse, which will cause a tendency to fracture the drill.

Another consideration of much importance is that of correct grinding. Much loss of output follows the use of drills incorrectly ground, as, for instance, when ground out of centre; when sufficient power is lacking to drive the machine efficiently, correct grinding becomes doubly important.

Thickness of point also requires special attention, and if this were given during inspection when new drills were received, it

is possible some interesting results would follow. The point of the drill is the most inefficient part of its cutting edge, and, the thicker the point, the more difficult is penetration rendered, and also the more power is required. The design of the twist drill calls for the web to be thicker near the shank than at the point, and a drill in which this is appreciably thicker than required is often better scrapped than used; it should certainly be returned to the maker. In any case, thinning of the point, as the drill is used-up, becomes essential, and in any tests of drills that are made this feature requires attention.

There is room for a considerable amount of education as to the possibilities of feed with twist drills. Comparatively little has been done in this respect, and in some instances the value of the different feed changes is not even specified, the driller working in the dark. Where this is the case, and no steps are taken by the shop authorities to provide this information, it is not to be wondered at if the rate at which drilling is done is variable and low.

The author remembers a recent incident where, with a 1 inch twist drill, on a rough job, the rate of penetration was 1 inch per minute. It was suggested that the machine and drill would stand a penetration of at least 3 inches per minute, but the driller was doubtful, and asked to be relieved of the responsibility of any damage to the machine or the drill. He was given the necessary assurance, but after the machine was started he retreated behind it to a distance of some yards, and awaited events. Needless to say, the machine and the drill survived without disaster of any kind overtaking them; the driller was genuinely amazed, but the significant facts are that after many years of drilling he was so ignorant of the possibilities as indicated, and that at the same time his foreman was satisfied with the output given.

In this connection, an excellent practice has been introduced by Messrs. Archdale of Birmingham, by the fixing of a plate to their machines, indicating the rate of penetration a stated size of drill can be given when working in mild steel. Such a guarantee will have a useful educational value.

The rate of feed actually possible will, as stated, depend upon the power of the machine used, but good high-speed drills should be able to stand the feeds given in the table on the next page.

The speeds at which drills can be driven are dependent mainly upon three factors: the material of which the drill is made, the class of material being cut, the adequacy of the supply of lubrication.

Dealing with the latter first, the absence of efficient methods of lubrication is responsible for an undue wastage of drills as well as for a rate of output which is less than would otherwise be possible, owing to the difficulty of keeping the drills cool and the consequent necessity for using lower speeds.

The cutting speeds which twist drills will stand when working in a good quality mild steel, to give a fair length of life without grinding, are about 60 feet per minute. Mild steels, however, vary

so much in their constituents and cutting qualities that it is not possible to generalize. The author calls to mind a twist drill test where two twist drills were running at a rate of penetration of 3 inches per minute, in a multiple spindle machine, drilling railway wagon angles. The two drills ran for approximately 12 hours without grinding, during which time 732 holes were drilled by one drill and 535 holes by the other. The conditions were of the roughest; the machine was old, and the location of the drills in the jig holes was not carefully adjusted.

In another case a $\frac{7}{16}$-inch twist drill was run satisfactorily in mild steel at a cutting speed of 72 feet per minute and 90 feeds per inch—.011 of an inch per revolution—giving a penetration of 7 inches per minute. Over against this, drills often fail at speeds and feeds which are much lower. A table of the kind shewn below is desirable in each works where drilling is done.

SPEEDS AND FEEDS FOR DRILLING. (No. 2)

HIGH-SPEED DRILLS.

Diameter of Drill.	Class of Material.											
	Brass.				Mild Steel.				Cast Iron.			
	120 feet per Minute.				60 feet per Minute.				50 feet per Minute.			
	R.P.M.	Feed per Rev.	Feeds per Inch.	Penetration per Min.	R.P.M.	Feed per Rev.	Feeds per Inch.	Penetration per Min.	R.P.M.	Feed per Rev.	Feeds per Inch.	Penetration per Min.
$\frac{1}{8}$	3667	.003	333	11.0	1833	.003	333	5.5	1528	.004	250	6.1
$\frac{3}{16}$	2445	.004	250	9.8	1222	.004	250	4.9	1019	.005	200	5.1
$\frac{1}{4}$	1833	.005	200	9.2	917	.005	200	4.6	764	.006	167	4.6
$\frac{5}{16}$	1467	.006	167	8.8	733	.006	167	4.4	611	.007	143	4.3
$\frac{3}{8}$	1222	.007	143	8.6	611	.007	142	4.3	509	.008	125	4.1
$\frac{7}{16}$	1048	.008	125	8.4	524	.008	125	4.2	437	.009	111	3.9
$\frac{1}{2}$	917	.009	111	8.3	458	.009	111	4.1	382	.010	100	3.8
$\frac{5}{8}$	733	.010	100	7.3	367	.010	100	3.7	306	.011	91	3.4
$\frac{3}{4}$	611	.011	91	6.7	306	.011	91	3.4	255	.012	83	3.1
$\frac{7}{8}$	524	.012	83	6.3	262	.012	83	3.1	218	.0135	74	2.9
1	458	.013	77	6.0	229	.013	77	3.0	191	.015	67	2.9
$1\frac{1}{8}$	407	.014	71	5.7	204	.014	71	2.9	170	.0165	60	2.8
$1\frac{1}{4}$	367	.015	67	5.5	183	.015	67	2.7	153	.018	56	2.8
$1\frac{3}{8}$	333	.016	63	5.3	167	.016	63	2.7	139	.018	56	2.5
$1\frac{1}{2}$	306	.016	63	4.9	153	.016	63	2.4	127	.018	56	2.3
$1\frac{5}{8}$	282	.016	63	4.5	141	.016	63	2.3	118	.018	56	2.1
$1\frac{3}{4}$	262	.016	63	4.2	131	.016	63	2.1	109	.018	56	2.0
$1\frac{7}{8}$	244	.016	63	3.9	122	.016	63	1.9	102	.018	56	1.8
2	229	.016	63	3.7	115	.016	63	1.8	96	.018	56	1.7
$2\frac{1}{4}$	204	.016	63	3.3	102	.016	63	1.6	85	.018	56	1.5
$2\frac{1}{2}$	183	.016	63	2.9	92	.016	63	1.5	76	.018	56	1.4

Reaming. Reaming as an operation is similar to drilling, but with the cutting speed used slower and the feeds much faster. The method of estimating the rate of output is similar to that used in drilling. The amount of material left for removal by the reamer, is a big factor as regards output, and with the use of solid reamers reaming has been treated as a most uncertain job, the rate of output being very low. The manufacture of shell reamers, however, has

shewn the possibilities in this respect to be much greater than before, and, in mild steel, the author has seen $\frac{1}{64}$ of an inch removed from a $1\frac{1}{4}$ inch diameter hole, 3 inches long, in 1 minute, leaving a good hole both for size and finish.

The speeds and feeds used for reaming depend even more than those for drilling upon a good supply of lubricant, because size and finish of holes are involved. Where the size of the reamer will stand the strain, a slow cutting speed and a coarse feed are likely to give the better results.

The time required for reaming depends as much on the design of the reamer as on the depth of hole, not only as to whether the reamer is of the solid or shell type, but, with the solid reamer, as to the length of the leading taper. While a greater length of travel is necessary than the actual depth of hole, it does not follow that the whole length of the reamer should be fed through at all or, if so, at the same rate as required for the first portion. So soon as the tapered or leading portion of the reamer is right through the hole, it should be possible for the remaining portion to be fed through at much faster rate. A rule such as the following will be found useful.

Allow the reamer to be fed through at the appropriate feed per revolution—this will vary from 20 to 80 feeds per inch, in accordance with the class of material being cut and the amount removed, the type and size of reamer, and the depth of hole and the cutting speed used. When the full diameter portion of the reamer is right through, allow the remainder at treble the feed, or one third at the normal feed. This allowance should not be more than an amount equal to 2 diameters. Thus, for a 1 inch diameter hole, 1 inch through, and a chucking reamer with flutes 2.75 inches long, the allowance for travel would be 1 inch plus the lead, say .25 of an inch, plus .5 of an inch $(1.5 \div 3) - 1.75$ inches in all.

Counterboring, facing and countersinking are somewhat similar operations, and the method of estimating is the same. The feeds and the cutting speeds used will in most cases be slower than those used in drilling proper. The rate of feed will also be affected by the size of the cutter bar, and the diameter of the counterbore or the face which is to be machined. There can be no standard in this respect, and feeds can vary from .002 of an inch per revolution, or 500 feeds per inch, to .015 of an inch or 64 feeds to the inch.

Countersinking is more usually done with a solid tool than with a cutter bar, and the flat drill gives equally good and, in some materials, much better results than does the twist drill. With a flat drill a " lip " can be ground on each cutting edge, which greatly improves the efficiency of the tool. The method of estimating is the same as with drilling.

Tapping. No change in formula is called for in connection with tapping. The threads per inch are used as the feeds, and time must be allowed for the withdrawal of the tap as well as for the tapping itself. The tap should be withdrawn at a rate of speed two or three times as great as that used for tapping, and it is convenient,

once the ratio is known, to cover this by allowing one half or one third of the cutting time, as the case may be.

The speed used in tapping is the lowest of all "drilling" operations, 12 to 15 feet per minute being suitable for mild steel, cast iron being about the same, although if soft, 20 feet can be obtained. Brass and gun-metal can be tapped at upwards of 30 feet, but seeing machine tapping is generally required in connection with short holes, the fast feed combined with fast speed makes the starting of taps somewhat difficult, and for this reason soft metals are often cut at speeds which are less than the taps will stand.

An estimate for a drilling operation should be taken out as follows.

Let it be assumed that, in an iron casting, 10 holes have to be drilled, 4 of which have to be tapped, 4 others countersunk, 2 reamed and 6 faced. A free-hand sketch of the job can be made if required—in perspective is the most convenient—and the operation should be detailed as below. The depth of the holes will be taken as being .75 of an inch.

BRACKET GUIDE.

	Drill, ream and face,	2—1 in. holes.	Order No. 324.
Part No. 1/634.	,, tap and face,	4—.5 in. ,,	No. off 10.
Mat. C. I.	,, and countersink,	4—.5 in. ,,	Machine No. D 62.

		Minutes.
Drill 2—1 in. holes - - - - -	$\frac{1.3 \times 67 \times 2}{191}$	.91
Ream 2 ,, - - - - -	$\frac{1.6 \times 32 \times 2}{96}$	1.06
Drill 4—.5 in. tapping holes - -	$\frac{.65 \times 100 \times 4}{382}$	.68
Drill 4—.5 ,, holes - - -	$\frac{.65 \times 100 \times 4}{382}$	.68
Face at 1 in. ,, - - - -	$\frac{.06 \times 500 \times 2}{38}$	1.58
Face at .5 in. ,, - - - -	$\frac{.06 \times 500 \times 4}{76}$	1.58
Countersink 4—.5 in. holes - -	$\frac{.3 \times 100 \times 4}{130}$	.93
Tap 4—.5 in. holes - - - - -	$\frac{1.25 \times 1 \times 12 \times 4}{96}$	.63
Return taps - - - - -		.32
		8.37
Add 25 per cent. for contingencies - - - - -		2.09
Setting job and jig - - - - - - - -		3.00
Change hole to hole, job clamped - - - -		6.5
Tools, handling and changing - - - - - -		2.66
Gauging as required - - - - - - -		2.0
		24.62

Estimated time, say 25 minutes.

It will be found useful to fix a standard of allowances for the changing of drills in accordance with their size and, if needs be, the number of sockets to be removed. This is not often done, all such items being left to the discretion, not of one rate-fixer, but of many; consequently different ideas obtain, and it is possible for an estimate to be materially affected by the allowances made.

The work done on drilling machines is admirably adapted for tabulation, which can be carried out to a considerable degree; in fact, apart from the time required for setting, which is bound to vary according to the nature of the job, tabulation can be carried so far that the need for further estimating can be almost eliminated.

One of the most useful tables is one built up for use either on types of machines or for specified jobs, which will give the time required for drilling holes of different diameters and depths. The times quoted in such a table should be exclusive of setting, which varies with different jobs, but should include allowances for the contingencies involved by drilling. Under this head, time should be allowed for replacing or grinding drills, and, also, to cover fatigue. The latter will depend upon the size and depth of the holes, because, obviously, the shorter the duration of cutting the more active the operator must be, and the more frequent the chances of uncertain movements being made. Where the depth of hole exceeds the diameter by more than three diameters, the chips may cause trouble and call for clearing, time for which must be allowed.

This table could be used for holes drilled with or without jigs, provided a column be added to cover centering, but it would be necessary to indicate whether or not the allowance for the "point of the drill" was included. It would be quite simple to arrange that the time allowed for a given "depth of hole" should include that for the point, and when jigs were not used, for the "allowance for point" to be for handling only; that is, the "depths of holes" could always be read at their face value, the time required for the point being included. The time required to move from hole to hole could also be included, but if it were desired to use the table for more than one size of machine, the allowance for moving from one hole to another could be affected as the size was increased or decreased.

In the latter case it would be more correct to add a column for this purpose, but that would depend upon the use the table was to be given. It is possible to use a table built up as described for more than one kind of material by multiplying by different factors. Thus, if the table be drawn up for mild steel, which is the most commonly used material, and the time for drilling soft brass is required, then the the time quoted in the table for a given size can be multiplied by the respective factor, as, say .4 or .5, and the time required for drilling brass be obtained. These different

factors can be simply estimated as follows, a 1 inch hole 1 inch diameter being taken for purposes of convenience.

$$\text{Factor} = \frac{\text{cutting speed used in table}}{\text{cutting speed for } x \text{ material}}.$$

For example, let it be assumed that the table is built up on the basis of drilling mild steel, and it is desired to use same for brass work. The feed will be taken as being the same in each case, but the speed for mild steel will be taken as 60 feet per minute, and for brass as 120 feet per minute. Then the factor for multiplying the "steel" time in order to obtain that for drilling brass, will be .5; in other words, the time for steel will be divided by 2. If the feeds used, varied, the factor would be obtained by using the respective estimated times, or the rates of penetration per minute, instead of the cutting speed. Of course, where reference to tables is frequently made, it may be more economical to have a table for each class of material used than to be constantly making additional calculations.

In the table given as an example time is allowed, in each case, for the point of the drill, but the time for centering in the end column covers the handling of the centering only, not the sinking of the drill. A table can be built up on these lines to suit the needs of individual works. As with all tables, the times given are in

DRILLING TABLE. (No. 3)

"THROUGH" HOLES. MATERIAL—MILD STEEL.

Diameter.	Depth of Hole.																				Add for Centering.
	1/8	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3	
1/8	.04	.07	.10	.13	.16	.19	.22	.25	.28	.31	.34	.37	—	—	—	—	—	—	—	—	.10
3/16	.05	.08	.12	.15	.18	.22	.25	.28	.32	.35	.38	.42	.45	.48	.52	.55	—	—	—	—	.12
1/4	.06	.10	.13	.17	.20	.24	.27	.30	.34	.37	.41	.44	.48	.51	.55	.58	—	—	—	—	.14
5/16	.07	.11	.14	.18	.21	.25	.28	.32	.35	.39	.43	.46	.50	.53	.57	.60	—	—	—	—	.16
3/8	.08	.11	.15	.19	.22	.26	.29	.33	.37	.40	.44	.47	.51	.55	.58	.62	—	—	—	—	.18
7/16	.09	.12	.16	.19	.23	.27	.30	.34	.38	.41	.45	.49	.52	.56	.59	.63	.70	.78	.85	.92	.20
1/2	.09	.13	.17	.21	.25	.29	.33	.37	.41	.45	.49	.53	.57	.61	.65	.69	.77	.85	.92	1.0	.22
5/8	.12	.16	.20	.24	.28	.33	.37	.41	.45	.49	.53	.57	.61	.65	.69	.73	.82	.90	.98	1.1	.24
3/4	.15	.19	.24	.28	.33	.37	.42	.46	.57	.55	.59	.64	.68	.73	.77	.82	.91	1.0	1.1	1.2	.26
7/8	—	.22	.27	.32	.37	.41	.46	.51	.56	.60	.65	.70	.75	.79	.84	.89	.98	1.1	1.2	1.3	.28
1	—	.26	.31	.36	.41	.46	.51	.56	.61	.66	.72	.77	.82	.87	.92	.97	1.1	1.2	1.3	1.4	.30
1 1/8	—	.28	.33	.39	.44	.49	.54	.60	.65	.70	.75	.80	.86	.91	.96	1.0	1.1	1.2	1.3	1.4	.32
1 1/4	—	.32	.37	.43	.48	.54	.59	.65	.70	.76	.81	.87	.92	.98	1.0	1.1	1.2	1.3	1.4	1.5	.34
1 3/8	—	—	.40	.46	.52	.57	.63	.69	.74	.80	.86	.91	.97	1.0	1.1	1.2	1.3	1.4	1.5	1.6	.36
1 1/2	—	—	.46	.52	.59	.65	.71	.77	.83	.90	.96	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.6	1.8	.38
1 5/8	—	—	.53	.59	.66	.73	.79	.86	.93	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.7	1.8	1.9	.40
1 3/4	—	—	—	.65	.72	.80	.87	.94	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.7	1.8	2.0	2.1	.42
1 7/8	—	—	—	.73	.80	.88	.96	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.3	.44
2	—	—	—	.80	.88	.96	1.0	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.1	2.3	2.4	.46
2 1/4	—	—	—	.97	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.3	2.4	2.6	2.8	.48
2 1/2	—	—	—	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.8	3.0	3.2	.50

Time allowed covers cutting and contingencies, and point of drill.

	Sensitive.	Upright.	Radial.	
Shift hole to hole jigwork - - -	.05	.1	.1	minutes.
,, ,, ,, fixed - - -	—	.25	.33	,,

Add time to set in jig or on table. Centering allowance not needed for jig work.

For brass work allow one half above times. For class "A" work add 25 %. For weak machine allow difference between rate and performance as "extra."

minutes, and are estimated times, that is, they represent the time in which the work ought to be done, not the job rates. To obtain the job rates, that addition is necessary which is appropriate to the system in use.

A table in which is given the diameters of countersinks of different angles and thicknesses of hole will be found useful, while if one standard angle only be called for, then in the one table could be conveniently embodied the cutting times for the various depths of countersinks required. Such a table could be built up in the following form :

COUNTERSINK TABLE. (No. 4)

ANGLE OF COUNTERSINK x. MATERIAL M.S.

Depth of Counter-sink.	Diameter of Hole.										
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
$\frac{1}{16}$											
$\frac{1}{8}$											
$\frac{3}{16}$											
$\frac{3}{4}$											

Similar tables can be conveniently arranged for facing and counterboring, although where " up-cuttering " is done the strength of the cutter bar is controlled by the size of the hole supporting the bar. Work of this description would be best handled under diameters of hole and face, and the amount of material to be removed.

Tapping tables can be built up, the time being stated for 1 tap for preference, to be doubled when two taps are used. As with other drilling machine tables, the time for shifting from hole to hole should be kept separate, excepting there be a separate table for each class of material cut. Tapping tables should be built up similarly to those for countersinking. For convenience in estimating, once the relation of cutting and return speeds have been established, it is permissible to average the cutting times, and by so doing avoid a calculation. Thus, where the reverse speed is equal to 2 to 1 of the cutting speed, if the reverse revolutions be reduced for the purpose by one third, or the cutting revolutions be increased by a similar amount, and two cuts be allowed, the resultant figures will be the same as though the cutting and reverse time were estimated separately. Should the reverse be three times as fast as the cutting speed, one half of the reverse revolution will give the desired result.

The table should be arranged to cover tapping time plus contingencies only; shifting from hole to hole should be allowed for in a separate column. As with drilling, the length of travel will be something greater than the depth of hole, and this factor should be borne in mind when estimating. Seeing blind holes often require to be tapped, and the tap cannot go through, it may be found an advantage, where both through and blind holes are common, for such a table to be built up on the basis of the depth of tap travel rather than depth of hole. The basis of the table should be some such standard of threads as Whitworth, but whatever standard be used, if the threads actually being tapped are finer or coarser than the standard, the amount of time required will be affected accordingly; thus, at the same cutting speed, 12 threads would take longer to cut in a 1 inch diameter hole than would 8 threads, although in this connection, the cutting speed used can be faster for the tapping of fine threads than for coarse ones, a factor which, when tapping alone is being done, requires to be given special attention. The reason for fine pitched threads taking a greater time to tap than threads of coarser pitch is, of course, the slower rate of feed. This feature is dealt with at some length in Chapter XXVIII.

CHAPTER XXVI

PRODUCTION ESTIMATING

SHAPING—SLOTTING—PLANING

Of the various machining processes in engineering manufacture, shaping, slotting and planing are amongst the simplest, so far as actual performance is concerned, and the method of estimating the rate of output which is possible reflects this simplicity.

While three processes will be dealt with in this chapter, the differences between them are but slight, and are a matter of application rather than of principle. Cutting is done in each case by the means of a reciprocating motion, the main difference being that in the case of shaping and slotting, cutting is done as a result of motion being imparted to the tool, while, with planing, the motion is imparted to the piece being machined. Slotting might be described as vertical shaping, shaping and planing being performed horizontally.

To estimate the rate of production for these processes, it will be presumed that there is general knowledge of the shop conditions, and that the requirements as to the class of finish needed and the cutting capacities of the tool steel used in the materials which are to be machined are known, so that the standard set up by the management can be the basis of the estimate, and not that of the individual practices of the different workers.

The class of material to be machined being known, and, consequently, the cutting speed, it is necessary to ascertain how closely the machine speeds are to the cutting speeds desired. This is more important with machines of the reciprocating type, and is more especially so with the larger shaping and slotting machines, and all planers, than with lathes and other machines where the cutting is continuous, because, not only is the work on these machines confined more to cutting time than on some others, but the strokes per minute do not indicate the true cutting speed. A complete cycle on a machine of the reciprocating type consists usually of a cutting and an idle stroke, forward and return. The speed of the cutting stroke is controlled by the cutting capacity of the tool steel in use and the material being cut, but the idle or return stroke is not so controlled and can be considerably increased, the limit being mechanical practicability rather than any consideration of the pieces being machined.

It is not uncommon to find that this factor is ignored and the cutting speed of a shaping machine calculated thus :

$$\text{feet per minute} = \frac{\text{length of stroke in inches} \times 2 \times \text{number of strokes}}{12}.$$

The multiplication by 2 is to cover the cutting and the return strokes, while the division by 12 is to give the answer in feet. Obviously the result cannot be correct, as will be seen from the following illustration.

A machine is being run at 10 strokes per minute, the length of stroke being 18 inches, the cutting speed required being 30 feet per minute. Superficially, the speed required is being obtained. But the machine is designed so that the return stroke takes $33\frac{1}{3}$ per cent. less time than does the cutting stroke, thus making the ratio of the time of cutting to that of return as 3 is to 2. Thus the 10 cutting strokes, which are equal to 15 feet cut, take 36 seconds out of the minute, and the 10 return strokes take the remaining 24 seconds, and the actual cutting is done at the rate of 25 feet per minute, not 30 feet as shown when the average speed is calculated. Therefore if job rates were based on the number of strokes calculated on average speed instead of on actual cutting speed they would be high, while, if there were any restrictive rule in the workshop as to the amount of earnings per hour which should be earned or paid, independently of whether the manufacturer or the workers were responsible for its existence, the output would be low accordingly. The number of strokes required per minute for this length of stroke and cutting speed is 12 not 10, and the calculated cutting time resulting from the use of 10 strokes would be 20 per cent. too much.

It will also be found that machines of different makers are provided with different ratios of cutting and return speeds, these differences being sufficient to have an appreciable effect upon the output, and if these are not considered in estimating, then job rates will present unequal opportunities to workers accordingly as the speed ratio of the machine worked, cutting and return, is greater or less than that allowed for in the estimate.

Thus if the speeds of machines be compared whose ratios are unequal—these are sometimes found to be 3 to 2 and 2 to 1, etc.—the importance of the difference will be appreciated if the actual cutting speed obtained be considered. The length of stroke is assumed to be 18 inches.

Ratio Cutting to Return.	Strokes per Minute.	Cutting Speed in Feet per Minute.		Strokes Required to give Cutting Speed of 30 Feet per Minute.
		Average.	Actual.	
Equal	10	30	30	10
3 to 2	10	30	25	12
2 to 1	10	30	22.5	13.3

In ascertaining the ratios of different machines, it will be found that the methods used to obtain same are gearing, in the case of single belt machines, and different sized pulleys, where two belt machines are involved. To obtain this ratio is a matter of ordinary calculation, although where large planing machines are concerned the timing of the actual stroke is more frequently resorted to.

For the purpose of simplifying both the calculation and the records, and also as enabling a ready means of comparison to be made, it is advisable, once the factors are known and recorded, to eliminate the references to ratio by adopting what may be called a cutting factor. This is particularly desirable where two belt machines are concerned, because, unlike the one belt machines with their fixed cone speeds, the strokes obtainable per minute being dependent upon the length of stroke required, can be varied at pleasure and, excepting there be some factor into which the length of stroke can be divided, and so give the number of strokes, it becomes a question of timing such a machine on each occasion a new length of job is to be machined, or of preparing a table which would give the information needed in the shape of number of strokes per minute for given lengths of stroke. Such a table is given below.

SPEED TABLE. SLOTTING AND SHAPING. (No. 5)

STROKES PER MINUTE FOR STATED CUTTING SPEEDS AND RATIOS.

Length of Stroke.	Ratio—Cutting to Return.											
	1 to 1				3 to 2				2 to 1			
	Cutting Speed in Feet.											
	20	30	40	50	20	30	40	50	20	30	40	50
	Strokes per Minute.											
1	120	180	240	300	144	216	288	360	160	240	320	400
2	60	90	120	150	72	108	144	180	80	120	160	200
3	40	60	80	100	48	72	96	120	53.3	80	107	133
4	30	45	60	75	36	54	72	90	40.0	60	80	100
5	24	36	48	60	28.8	43.2	57.6	72	32.0	48	64	80
6	20	30	40	50	24.0	36.0	48.0	60	26.7	40	53.3	66.7
7	17.1	25.7	34.3	42.8	20.6	30.1	41.1	51.4	22.9	34.3	45.7	57.1
8	15.0	22.5	30.0	37.5	18.0	27.0	36.0	45.0	20.0	30.0	40.0	50.0
9	13.3	20.0	26.7	33.3	16.0	24.0	32.0	40.0	17.8	26.7	35.6	44.4
10	12.0	18.0	24.0	30.0	14.4	21.6	28.8	36.0	16.0	24.0	32.0	40.0
11	10.9	16.4	21.8	27.3	13.1	19.6	26.2	32.7	14.5	21.8	29.1	36.4
12	10.0	15.0	20.0	25.0	12.0	18.0	24.0	30.0	13.3	20.0	26.7	33.3
13	9.2	13.8	18.5	23.1	11.1	16.6	22.2	27.7	12.3	18.5	24.6	30.8
14	8.6	12.9	17.1	21.4	10.3	15.4	20.6	25.7	11.4	17.1	22.9	28.6
15	8.0	12.0	16.0	20.0	9.6	14.4	19.2	24.0	10.7	16.0	21.3	26.7
16	7.5	11.2	15.0	18.7	9.0	13.5	18.0	22.5	10.0	15.0	20.0	25.0
17	7.1	10.6	14.1	17.6	8.5	12.7	16.9	21.2	9.4	14.1	18.8	23.5
18	6.7	10.0	13.3	16.7	8.0	12.0	16.0	20.0	8.9	13.3	17.8	22.2
19	6.3	9.5	12.6	15.8	7.6	11.4	15.2	18.9	8.4	12.6	16.8	21.0
20	6.0	9.0	12.0	15.0	7.2	10.8	14.4	18.0	8.0	12.0	16.0	20.0
Cutting Factors.	120	180	240	300	144	216	288	360	160	240	320	400

The ratio being fixed, the conditions obtaining in this connection must be accepted as correct or used until altered, and must be

reflected in the estimate, therefore in the cutting factor. Then the item which usually matters is the amount of cutting which can be done in one minute; that is, the number of feet of tool travel in the forward or cutting direction in that time.

Assuming that the cutting speed required and provided for is 30 feet per minute, and that the ratio of cutting speed to return is 3 to 2, and the length of stroke is 18 inches, then

$$A = 1 \text{ minute (60 seconds)};$$

let ratio $$B = \frac{\text{portion of time cutting}}{\text{time cutting and return}} = \frac{3}{5}$$

$$\text{and cutting time} = A \times B = \frac{60 \times 3}{5} = 36 \text{ seconds.}$$

Let D = cutting speed in inches per minute,
E = seconds cutting time per minute,
F = seconds per minute,

$$\text{then cutting factor in inches} = \frac{360 \times 36}{60} = 216 \text{ inches.}$$

This can be simplified by applying the ratio direct to the cutting speed required, thus:

$$\frac{360 \times 3}{5} = 216 \text{ inches cutting factor.}$$

Then the length of stroke being known, the number of strokes required per minute are obtained thus:

$$\text{length of stroke} = \frac{\text{cutting factor}}{\text{length of stroke}}$$

and for the example taken

$$\frac{216}{18} = 12 \text{ strokes per minute.}$$

Before leaving the question of strokes per minute it may be thought that with the single belt machines and their fixed speeds there is less need of a cutting factor than with the two belt machines; that the most suitable speed on the machine should be used and the estimate taken out accordingly.

This is a point which has been much debated in connection with many classes of machines. Theoretically, to do so is correct, but to obtain absolute accuracy in this respect would mean a different rate for practically every machine. If this be attempted, then slight differences in feed and in the strength of machine, etc., could be taken into consideration, but the extent to which this treatment could be extended would depend upon local conditions, the nature of the product, and the amount of repetition possible. An example of conditions which would frequently arise is quoted.

A single belt shaping machine has 4 speeds provided, two of which give 12 and 18 strokes to the minute respectively. For a

given job which requires a 12 inch stroke, 18 strokes per minute give the required cutting speed. But the next job requires a $12\frac{1}{2}$ inch stroke. Which of the two speeds is to be used? Such a rule would indicate 12 strokes, a reduction of $33\frac{1}{3}$ per cent. Now there must either be definite cutting speeds recognized and used as a basis for estimating, or there must be big discrepancies between the rates allowed for jobs whose dimensions are nearly alike, owing to the comparatively few speed changes available. Thus, for a machine, as the one referred to above, where two of its adjacent speeds give 12 and 18 strokes respectively for a cutting factor of 216 inches, the appropriate length of stroke would be 18 inches and 12 inches; but jobs requiring strokes with lengths varying anywhere between the two quoted would have to be machined, and at some stage between the two a decision would be required as to whether 12 or 18 strokes were to be used. If it be assumed that the division be held to take place at the 15 inch length of stroke, then two jobs, one requiring a stroke 15 inches long and the other a stroke $15\frac{1}{4}$ inches long, would be done one using 18 strokes, and the other 12 strokes, while the difference in cutting time allowed, because of that quarter of an inch, would be 50 per cent. Such a difference, when it was less, would not be accepted readily by the workers, while, owing to the varying speeds of different machines, confusion of the worst kind would be almost certain to follow.

With an ordinary class of work and with small machines it is quite often the practice, in calculating the number of strokes required, to use that cutting factor which is appropriate to the machine, and the compromise is one which gives not unsatisfactory results.

On the other hand, where large machines of either class are concerned, and, in particular, when one rate of cutting speed only is provided, it is advisable to obtain a cutting factor for each machine, and to make a practice of fixing separate rates for the machines which come under each factor. This is unavoidable, because a worker using a one-speed machine has no alternative but to use the speed provided, however light the cut may be, whereas, with a machine with a choice of speeds, a worker, if he found one speed slightly on the low side, would, perhaps, use the next higher speed, or take a heavier cut, using a faster speed for the later cut, thus counteracting the disability of an insufficient range of speeds.

In connection with two belt machines and the cutting factor, it is necessary to call attention to the loss of motion and time which takes place at each end of the stroke, and this becomes more serious with short jobs and fast running machines than with long jobs and slow running machines. With the reversing of the belts the momentum of the machine, table, job and gearing, has to be overcome at each end. This reversal calls for work to be done by each of the belts in turn, and during this overcoming, first of the motion and then of inertia, belt slip takes place, and, as will readily be seen, time must be lost. Thus at the beginning and end of each

stroke the rate of movement is less than that of the normal speed rating of the machine, while the shorter the length of stroke taken, the greater proportion of the time taken by each stroke, does this slowing down and starting up become. The difference thus made is of serious moment, as will be seen from the accompanying table. Observations were taken over a large number of machines as they were in ordinary use in the workshop, and these showed that, compared with the effective cutting speed on long lengths of stroke, the cutting factors were reduced as shewn below :

Machine.	Cutting Factors for Different Lengths of Stroke.		Percentage Lost on Short Stroke.
	1 Foot.	8 Feet.	
A	120	270	55·5
B	190	260	26.9
C	160	250	36.0
D	172	280	38.6
E	166	240	30.8
F	88	166	47·0

Observations of this kind indicate the importance, first, of loading the planing machine table with work, so as to use the longest stroke possible, and secondly, of making sure that the planer belts are suitably adjusted, so that this loss of time at the beginning and the end of each stroke will be reduced to a minimum.

The use of variable speed motors requires no special comment in this connection, beyond this, that, seeing different classes of material require planing, the provision of a choice of speeds enables the softer materials to be planed more economically, inasmuch as with one speed provided only, except the speed pulleys be changed, all materials have to be machined at that one speed, and that speed is likely to be arranged to suit the hard rather than the softer materials. In modern planing machines, a most welcome provision is made for a change of speed by means of change gears. Where the planing work done, however, covers a variable class of materials, and the machines are provided with one speed only, the provision of variable speed motors is one which should not be lightly dismissed. In this connection the design of planing machines has been much improved of late years. They are now provided with tool boxes which cut on each stroke, thus eliminating the idle stroke, and, while a considerable increase in output becomes possible, the question of ratio is cut out.

Length of Stroke. The length of stroke to be allowed for falls next to be considered, and this will be seen to vary as between one and two belt machines. With single belt cone speed machines the length of stroke, while adjustable, is mechanically fixed, and being controlled by a rotary motion is repeated, identically the

same length, independently of the size of cut or speed of machine. With two belt machines, where the length of stroke is entirely controlled by belts through striking gear, the length of stroke is not obtained with so much precision, and whereas, on the mechanially controlled stroke, it is sufficient if the length of stroke be adjusted so as to clear the material being cut, by, say one half inch on large two belt machines, it is not uncommon to find that as much as 12 inches clearance is required. With a planer, the forward belt must be kept on sufficiently long to make sure the cut will be completed, and this is controlled by the depth of cut and the size of feed ; thus with a light cut the forward belt can be removed slightly earlier in the cut than with a heavy cut. This is another argument, of course, against the use of the planer for short jobs where that can be avoided ; equally for keeping belts in good condition.

If the machining of a job, 24 inches long, could be done equally well on a large shaping machine with a single belt cone speed drive and on a planing machine, the length of stroke required could vary on the two machines as much, probably, as shewn below.

	Length of Actual Cut.	Amount Required to clear both Ends Inclusive.	Total Length of Stroke.
Shaping Machine - - -	24 ins.	2 ins.	26 ins.
Planing Machine - - -	24 ins.	9 ins.	33 ins.

Thus, for such a job, nearly 30 per cent. more cutting time would be required on the planer than on the shaper, and the point requires to be borne in mind for purposes of economy in manufacture as well as in providing an equitable job rate.

Because of the fact that, on mechanically controlled stroke lengths, the changes of stroke speeds are fixed, a certain indifference is shewn, in some cases, to the actual length of stroke used. Machines can sometimes be seen in use where the tool is allowed to run past the job, say one inch each end when one half inch is sufficient making the stroke, say 8 inches instead of 7 inches long. A small matter possibly, but it has the effect of increasing the actual cutting speed by 14 per cent. The author has seen cases where the correction of a cutting stroke, which was too long, has avoided the use of the next slower speed, and, when foremen and estimators have not been sufficiently alert, men have been successful in proving the "necessity" of going down a speed simply by extending, unnecessarily, the length of stroke.

Features special to reciprocating machines having been dealt with, the question of the estimating of production can be proceeded with. It is presumed that Chapter XXIII. has been read, and the references to estimating generally noted ; then the possibilities of

feeds, depth of cut, roughing and finishing, etc., will have been appreciated.

Dealing first with the machining of plain faces, the shaping of two faces of a plain forged slab of steel will be considered, a fair finish being required on each face. The job, as can be seen from the sketch on page 274, is capable of being lifted by hand, and will be assumed to be held in a vice for the machining of the first face and to be clamped on to the machine table for the second face; that a one belt machine with mechanically controlled length of stroke will be used, the cutting factor being taken as 240, and the feeds used as 20 per inch.

The various details involved for the shaping required are as follows, the machine being assumed to be ready for the job.

1. Lifting job on to and off the machine table.
2. Setting and gripping job into position twice.
3. Removing material—cutting.
4. Gauging.
5. Withdrawing of table or ram at the finish of cuts.
6. Setting and starting new cuts.
7. Changing and setting tools.

The lifting on and off the machine table is a purely mechanical kind of operation, and will take something less than one minute; actually, in practice, the time for lifting, where mechanical appliances are not required, is included in the setting time. The setting is a slightly longer process although in this case no great difficulty is to be anticipated. Both job and setting are simple, and in the machining of the first face, dependent upon the amount of material left for removal, it may be desirable either to remove or to leave a maximum of the surplus material. The gauging of the first face is practically a visual operation, being done while the machine is running and the cut is being set. For the machining of the second face, it will be presumed that the vice will be removed, and that the job will be held on the machine table by clamps in the usual shaper manner. Gauging for the second face is of more importance than with the first, inasmuch as the final dimension is to be dealt with. This, however, will be greatly facilitated if the setting of the tool for the last cut is aided by the use of a slip or bar gauge of the Johanssen type, of the required thickness.

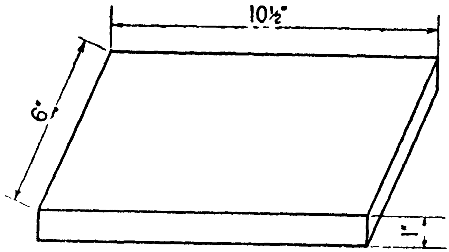
The withdrawal of the table or ram at the end of a cut is a matter which can be accurately timed in accordance with the distance to be covered; for the purpose of this estimate, the time required will be taken as being one quarter of a minute per withdrawal. Setting and starting new cuts will be allowed for similarly. The changing and setting of tools is called for either by a change of tool being required or by the tool becoming worn by use. In the case under consideration, it will be assumed that the tool is changed between each roughing and finishing operation, that is, twice for each face, and that each time the change is made the putting in and taking out takes one minute. The careful worker will make sure before

starting a cut that the tool is in such a condition that it is likely to go over the face without regrinding being required, but to cover this and other contingencies an allowance on cutting time of 20 per cent. will be made.

There is a decided advantage to be gained in keeping the cutting time in an estimate distinct from other items, as previously stated in Chapter XXIII and, in the estimate which follows, this is done.

PAD, GUIDE, CROSSHEAD

Part No. 4/621. Material, Forged M.S.



Order No. 324. No. off 10. Machine No. Sp. 21. Cutting Factor 240.

Operation—Shape 2 faces to thickness.
Material to remove—.25 of an inch.

Rough shape 2 sides $\frac{6.2 \times 2 \times 20}{20}$ - - - - -	12.4
Finish shape 2 sides $\frac{6.2 \times 3 \times 20}{20}$ - - - - - -	18.6
	31.0
Add for contingencies—20 per cent. - - - - -	6.2
Change and set twice :	
In vice $1\frac{1}{2}$ minutes : 4 clamps $3\frac{1}{2}$ minutes - -	5.0
Gauging - - - - - - - - - -	3.0
Withdrawal of table and start cuts - - - - -	2.0
Allowed for changing tools - - - - - -	4.0
Total estimated time - - - - - -	51.2

Allowed per batch for preparation—20 minutes.

All jobs, however, are not plain facing jobs, in fact the machining of plain faces of small area is more a milling proposition. The operations on the piece which was the subject of the estimate will be presumed to be complicated by the addition of a channel, .25 of an inch deep by $1\frac{1}{2}$ inches wide. The operation will not be materially altered, but additional time will be required for the removal of the material, the finishing of the face of the channel, and of the corners, the extra tools handled, and the additional gauging. The finishing cut will not be required over the whole width of face because the channel face will be finished first, and the plain face gauged from the bottom of the channel. The finishing cut on the face will then be less the width of channel.

With large jobs the proceedings are identical; the feeds can be much coarser, and the cuts taken, generally, much deeper. The question of multiple box machines is involved, two or more tool boxes being used on either one or two pieces. It may be that on a large face, as of a marking-off table, the face must be finished with one tool to ensure the greatest possible accuracy, but two tools could well be operated on the earlier cut. This would be dealt with by allowing one half the width of traverse on the roughing and the whole width for the finishing cut.

Where separate jobs are worked upon with individual tool boxes the results are that two pieces are machined in the same time as for one, but otherwise all tool handling, gauging, setting of jobs, remain the same per piece handled or, it may be, slightly increased owing to the more complicated handling and setting of two pieces on one machine.

On slotting machines are found, usually, the most complicated jobs which are done on machines of the reciprocating type; there, both plain and radial surfaces are required to be machined, but so far as the estimating of rates of output is concerned, the methods followed are not different, and practical knowledge of the work on the part of the production estimator is all that is required.

It is possible, however, to reduce the work of estimating in two ways; one of these is to use a machine factor, the other is to tabulate the estimates already worked out. The principles and advantages of this are treated at some length in Chapter XXIV. The principle of factorizing has a distinct application, although it should not be overlooked that, if it is possible to factorize, it is equally possible to tabulate. With shaping, slotting and planing, the machining done is very largely a matter of area of surface, although not entirely surface of job. The term surface must be understood to be the product of length of stroke and width of traverse. To illustrate: if two faces, one 3 inches by 3 inches, the other 6 inches by 6 inches, required to be machined, and say a shaping or slotting machine were to be used, the length of stroke might be considered as being, respectively, 4 inches and 7 inches. Then the area of the face to be machined and the potential area, *i.e.* that covered by the tool, would be as below.

Size of Job.	Comparative Areas in Square Inches.			
	A. Actual Area of Face.	Dimensions of Surface Covered by Tool.	B. Area of Surface Covered by Tool.	Excess B over A.
3×3	9	4×3.2	12.8	42.2%
6×6	36	7×6.2	43.4	20.5%

Thus if other things were equal, and the value of the large job were considered to be four times that of the small one, and the cutting time for the latter were 9 minutes, the large job would be allowed 36 minutes instead of 30.5 minutes.

A factor for shaping is really the equation

$$\frac{A \times B}{C},$$

when $A = 1$ inch of traverse.
$B =$ feeds per inch.
$C =$ strokes per minute 1 inch long.

Thus, assuming that on a given class of machine it was a normal performance to cut at the rate of 30 feet per minute, the factor being 216, and to remove material at the rate of 20 feeds with cuts .125 of an inch deep, the factor for that machine would be

$$\frac{1 \times 20}{216} = .0926 \text{ minutes.}$$

The cutting contingency could be included if desired, but, excepting the whole of the cutting portion of the estimate can be obtained by using the factor, there is every liklihood of this contingency allowance being made twice. With the use of a factor the formula

$$\text{cutting time} = \frac{\text{width} \times \text{feeds} \times \text{cuts}}{\text{strokes}}$$

would be replaced by

$$\text{cutting time} = \text{width} \times \text{length of stroke} \times \text{cuts} \times .0926.$$

While the formula looks more formidable than it really is, the claim is not so much that it saves time in working as that it tends to set up a standard. Reference might be made to an incident described in Chapter XXIV., where the use of a factor, not only eliminated trouble, but was the cause of the two higher of the four speeds provided on a shaping machine, being put into continual use, while the rust, which previously was obvious on the top two steps of the cone, through lack of use, was worn away and became a feature of the lower two steps.

The work concerned was the shaping of steel blocks for use as jigs. The dimensions of each block were different, and necessitated a new job rate, and, where the smaller sizes were concerned, each job rate fixed was objected to on the score of being insufficient. The machine was very light and was not capable of taking a cut greater than .0625 of an inch deep at 48 feeds. The cutting factor was 180. This gave the factor per square inch as .2926 minutes; actually .3 minutes was the factor used.

The estimates were then taken out thus:

$$\text{cutting time} = \text{width of cut} \times \text{no. of cuts} \times \text{length of stroke} \times \text{no. of sides} \times .3 \text{ minutes.}$$

Setting at 3 minutes per face.

Gauging and tool handling at 3 minutes per face, plus an allowance for changing machine, as required.

The cuts allowed were one per $\frac{1}{16}$ of an inch to be removed, plus one for finishing.

For the cutting of materials other than steel a different cutting factor only would be required.

The fact that it is practicable to use a cut-and-dried basis of this kind is an indication at once that a further step is possible, namely, the elimination of calculation and the tabulation of results so obtained. Shaping, slotting and planing, however, are processes which are frequently called for in first operations, where the amount of material to be removed from different pieces is likely to be variable, and, where this is the experience, it is not wise to take tabulation farther than to quote the time per cut of a given depth for stated areas.

Thus for every machine for which it has been found worth while to build up a cutting factor per square inch, tabulation would appear worth considering in a similar manner although, for such variable items as setting the jobs ready for cutting, it is advisable definitely to leave this outside the scope of the table, excepting such table was being prepared for particular use as for the shaping of blocks.

A sample form of table is shewn below. The basis of the table is a cutting factor of 216, and feeds of 32 per inch, from $33\frac{1}{3}$ per cent. to 16.6 per cent. being allowed for contingencies which

SHAPING TABLE. (No. 6)

Material—M.S. Cutting Factor, 216.
Feeds per inch, 32. Depth of cut, *x*.
Time given in minutes for 1 cut.
For Tool Steel × 1.8.
„ G.M. × .66.
Allow *x* minutes per face setting.
x „ „ gauging.
x „ „ tools.

LENGTH OF STROKE.

Width of Traverse.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.359																		
2	.741	1.09																	
3	1.09	1.60	2.12																
4	1.43	2.12	2.81	3.51															
5	1.78	2.64	3.51	4.37	5.23														
6	2.12	3.16	4.20	5.23	6.27	7.31													
7	2.47	3.68	4.89	6.10	7.31	8.52	9.73												
8	2.81	4.20	5.58	6.96	8.35	9.73	11.1	12.5											
9	3.16	4.72	6.27	7.83	9.38	10.9	12.5	14.0	15.6										
10	3.51	5.23	6.96	8.69	10.4	12.1	13.9	15.6	17.3	19.1									
11	3.85	5.75	7.65	9.56	11.5	13.4	15.3	17.2	19.1	21.0	22.9								
12	4.20	6.27	8.35	10.4	12.5	14.6	16.6	18.7	20.8	22.9	24.9	27.0							
13	4.54	6.79	9.04	11.3	13.5	15.8	18.0	20.3	22.5	24.8	27.0	29.3	31.5						
14	4.89	7.31	9.73	12.1	14.6	17.0	19.4	21.8	24.2	26.7	29.1	31.5	33.9	36.3					
15	5.23	7.83	10 4	13.0	15.6	18.2	20.8	23.4	26.0	28.6	31.2	33.8	36.3	38.9	41.5				
16	5.58	8.35	11.1	13.9	16.6	19.4	22.2	24.9	27.7	30.5	33.2	36.0	38.8	41.5	44.3	47.1			
17	5.93	8.86	11.8	14.7	17.7	20.6	23.6	26.5	29.4	32.4	35.3	38.2	41.2	44.1	47.1	50.0	52.9		
18	6.27	9.38	12.5	15.6	18.7	21.8	24.9	28.0	31.2	34.3	37.4	40.5	43.6	46.7	49.8	52.9	56.0	59.2	
19	6.62	9.90	13.2	16.5	19.8	23.0	26.3	29.6	32.9	36.2	39.5	42.7	46.0	49.3	52.6	55.9	59.2	62.4	65.7
20	6.96	10.4	13.9	17.3	20.8	24.2	27.7	31.2	34.6	38.1	41.5	45.0	48.4	51.9	55.4	58.8	62.3	65.7	69.2

are linked up with cutting, handling and the human factor; this percentage is reduced as the area of the cut is increased. The setting of job and of tools and the gauging allowances are not nor can be included, satisfactorily, in a table which is intended to

have general application, and should be left to be dealt with in accordance with the nature of the job and the circumstances. It is possible to deal with these items as indicated, when the conditions are specified.

A general table could be built up on another basis if desired, the chief advantage being that better use would be made of the space available; that there would be no repetition of estimates for the same areas, and by having more references made inside the given range, the application would be wider. Thus, if the table were based on areas, independently of references to length of stroke and width of traverse, the number of actual references would be increased. The only disadvantage would be that calculation of the length of stroke × the width of traverse would be necessary to obtain the area figure in order to use the table.

Over against this must be set the fact that neither length of stroke nor width of traverse will necessarily run in even inches, and, excepting the table taken out under those heads is extended to take odd dimensions, a by no means impracticable proposition, some mental comparison or arithemetic will be necessary. A sample table drawn up on the basis of area is shewn below.

SHAPING TABLE. (No. 7)

MATERIAL, M.S. CUTTING FACTOR, 216. FEEDS PER INCH, 32.

TIME GIVEN IN MINUTES FOR 1 CUT OF x DEPTH.

	AREA IN SQUARE INCHES COVERED BY TOOL.									
	0	2	4	6	8	00	20	40	60	80
0	—	.395	.741	1.09	1.43	—	—	—	—	—
1	1.78	2.12	2.47	2.81	3.16	17.3	20.8	24.2	27.7	31.2
2	3.51	3.85	4 20	4.54	4.89	34.6	38.1	41.5	45.0	48.4
3	5.23	5.58	5.93	6.27	6.62	51.9	55.4	58.8	62.3	65.7
4	6.96	7.31	7.65	8.00	8.35	69.2	72.6	76.1	79.6	83.0
5	8.70	9.04	9 38	9.73	10.1	86.5	89.9	93.4	96.8	100
6	10.4	10.8	11.1	11.5	11.8	104	107	111	114	118
7	12.1	12.5	12.8	13.2	13.5	121	124	128	131	135
8	13.9	14.2	14.6	14.9	15.3	138	142	145	149	152
9	15.6	16.0	16.3	16.6	17.0	156	159	163	166	169
10	17.3	17.7	18.0	18.4	18.7	173	176	180	183	187

The areas range from 2 to 1080 square inches in twos, up to 108, and in twenties beyond this number. The figures in the left-hand column should be read as tens or hundreds, accordingly as the first or second portion of the table is being used. Thus, for 64 square inches, read 11.1 minutes on the 6 line under 4; for 860 square inches, read 149 minutes on the 8 line under 60.

Tables can be built up to meet any known conditions, and of course can be adopted for planing work. Amongst others may be mentioned the slotting and shaping of radii, the squaring out of corners, the machining out of channels, solid keys and keyways, although for the latter, the keyway-cutting machine and the broaching machine are being increasingly used; the machining of double eyes, and the time for ripping or parting-off, can all be conveniently

tabulated, and when done can be of great use in the fixing of job rates and also in connection with estimating for tendering purposes.

Shaping Bevel Teeth. The estimating of the time for shaping bevel teeth is done on similar lines to other shaping work, the depth of tooth taking the place of length of traverse. Usually, the operation consists of two items roughing and finishing. The roughing portion is just a "gashing" or "ripping" operation, while the finishing is generally a single point tool process. Tabulation is a somewhat difficult matter, possibly more so than with plain gear teeth that are milled. One of the most satisfactory methods is to work up a number of factors for the various sizes of teeth and materials used, and use as follows:

$$\text{Estimated time} = (D \times N \times (L + .5) \times F) + (N \times .2) + 2 + \text{setting}$$

when

D = depth.
N = number of teeth.
L = length of ,,
.5 = clearance.
F = factor.
.2 = gauging per tooth.
2 = initial gauging.

Then the time for shaping 30 bevel teeth 1 inch long .18 of an inch deep with a factor of 5 would be as follows.

$$(.18 \times 30 \times 1.5 \times 5) + (30 \times .2) + 2 = 48.5 \text{ minutes.}$$

Time for setting remains to be added in accordance with the nature of the job.

The different designs of bevel gear cutters and also the automatic and non-automatic machines will require individual treatment, but the method generally followed should be on the lines given above. Where more than one machine is worked by one man, the factor should be reduced in an appropriate manner.

CHAPTER XXVII

PRODUCTION ESTIMATING—MILLING

THE process of milling differs widely from other cutting processes for metal, that difference being more particularly apparent in connection with the tools used. Cutting in most of the other processes is done locally by the use of single point tools, but with milling cutting can be done over the whole area of a surface. To a considerable extent, the milling machine in its various forms has superseded the shaping, slotting and planing machines, particularly on small work, while many operations which were formerly done on lathes or drilling machines can be economically handled on milling machines.

Although milling is used extensively on odd job work, it is found to be especially useful in the repetitive machining of flat faces, and economies in labour cost of almost incredible amounts have been made possible. With the single point tool, the repetition of performance cannot be obtained, within close limits of accuracy, excepting by the constant adjustment of tools, because the life of the single-point of the tool is short. Constant adjustment of tools calls for skill, and this restricts the use of any but skilled labour. On the other hand, the milling cutter, with its many cutting edges and, consequently longer life, can be relied upon to reproduce surfaces within reasonable size limits for much longer periods of cutting, and the milling machine has been developed to take advantage of this fact, opening up, thereby, a great opportunity for the cheapening of production.

Milling machines, however, are not used nearly as much nor as efficiently as they should be, in fact, there are some works where their value as repetition machines appears to be quite unknown. A few years ago the author saw a new machine shop equipped with approximately 200 machines of various types, the work to be done including a considerable amount of repetition work; but for the small flat work a large battery of shaping machines had been installed—not a single repetition milling machine.

Broadly speaking, there are two types of milling, horizontal and vertical. Originally these terms signified something more than the position in which the cutter was held. Horizontal milling

signified the use of a barrel mill, carried on an arbor supported at each end, while with vertical milling the cutter, solid or otherwise, was carried in the spindle only, the cutting end being unsupported. While the machines themselves were described and named in accordance with the manner in which the cutters were used, there are many modifications to-day, and it is becoming increasingly common to do "vertical" milling on horizontal machines and *vice versa*. So far as estimating is concerned, it is convenient to consider horizontal milling as signifying work done with a cutter supported at each end, and vertical milling as signifying the use of a cutter free at one end. In some works, the two are referred to as barrel milling and finger or end milling, and, independently of the improvements to milling machines, these references are fairly satisfactory.

There are several types of horizontal and vertical milling machines made to-day, although these descriptions apply more to the class of machine and less to the nature of the milling done on them than was formerly the case. The chief of these are as follows:

Horizontal Type.	Vertical Type.
Plain.	Plain.
Universal.	Profiling.
Lincoln.	Duplex.

These are too well known to need any description. All can be used for repetition work, but the "Lincoln" type and the profiling machines are essentially repetition machines and are not so economical when used on jobbing work.

The estimating of the rate of production, however, is similar for all types of milling machines, although the formula used differs from that common to other processes. With other processes two factors are usually considered, cutting speed and feeds per inch; with milling, one factor only is considered and that is feed per minute. It is possible of course to use a formula similar to that common to other processes, but no good purpose would be served thereby, because the question of diameter of cutter would become involved, and this, within fairly wide limits, has little significance.

The vital point is peripheral speed—the rate at which the cutting edges are brought into contact with the work and the amount of material removed by such contact. Thus, for purposes of illustration, if there were two cutters, whose cutting edges were of equal pitch but whose diameters were respectively 4 inches and 6 inches, and the revolutions per minute were arranged to give the same peripheral speed, the cutting results would be identical, although it is generally advisable to use cutters of small rather than of large diameter because of the smaller arc of contact.

It is unfortunate that this reference to feed per minute, in leaving out the question of cutting speed, should have had the effect of putting the importance of cutting speed at which milling is done into the background, and investigation of both the machine speeds

provided, as controlled by the driving pulleys, and of the speeds in actual use, would often indicate the most diverse practices.

The cutting speed at which milling cutters are used is as important a matter as is the cutting speed used in drilling or turning, and is a controlling factor in deciding the feed per minute possible. Thus, if it be presumed that the feed per minute for a milling cutter for a given material and depth of cut is 6 inches, and that a suitable cutting speed is 60 feet per minute, then if the number of teeth in the cutter be 25, the amount of material to be removed per tooth per revolution of cutter would be .0063 of an inch. If a feed of 6 inches per minute be obtained with the use of a cutting speed of 40 feet per minute, the milling cutter tooth is being given .0094 of an inch to remove, or 50 per cent. more than the amount considered to be satisfactory, thus impairing the life of the cutter, whatever may be the results as regards the finish of the job. On the other hand, to keep the feed per tooth right, when using the lower cutting speed, means to reduce the feed per minute to 4 inches.

The ideas regarding the question of feeds and speeds on milling machines can be humorous as well as significant. In one works, the output of a certain piece was found to be very small and investigation revealed that the speed in use was 60 feet per minute, while the feed was .75 of an inch per minute only. A good class of steel was being cut and a feed of two inches per minute was considered to be reasonably possible. The miller protested he could do no more and that his cutters would not stand a heavier cut. The man appeared to be a decent sort of chap, and a little education only appeared to be necessary. He was told his cutting speed was quite satisfactory, being high rather than low, but he was asked how much material was being removed per tooth at the speed in use. The answer was, "About a sixty-fourth of an inch." He was told this was not so, but, before working out the travel per minute this would give, he was asked if he would think the cutter should remove material at the rate of .002 of an inch per tooth. There was no doubt in his mind as to the possibility of this. He was amazed, however, to find that, with the feed in use, the amount of material being removed was approximately .0005 of an inch ; that the removal of .002 of an inch per tooth meant a feed of 2.88 inches per minute and that his idea of a sixty-fourth of an inch per tooth meant 22.5 inches per minute. Incredible, perhaps, but none the less a fact, and not an isolated case.

The time required to mill a given face can be obtained by the use of the following formula:

$$\text{cutting time} = \frac{\text{length of travel} \times \text{number of cuts}}{\text{travel per minute}}.$$

Length of travel, because of the radial form of the cutter, is usually greater than the length of the face being machined, and it is necessary in the estimating of production rates that the amount

by which the length of traverse exceeds the length of face, be allowed for and this requires, therefore, to be readily obtained. This is commonly referred to as " centre " travel, and its amount can be ascertained by means of calculation but, seeing the distance is different for every depth of cut and every diameter of cutter, and calculations, therefore, would be required most frequently, some shorter method is desirable. One quick method is shewn in

MILLING CUTTER DIAGRAM.
Indicating Length of Travel Required
For Various Depths of Cut and Diameters of Cutters.

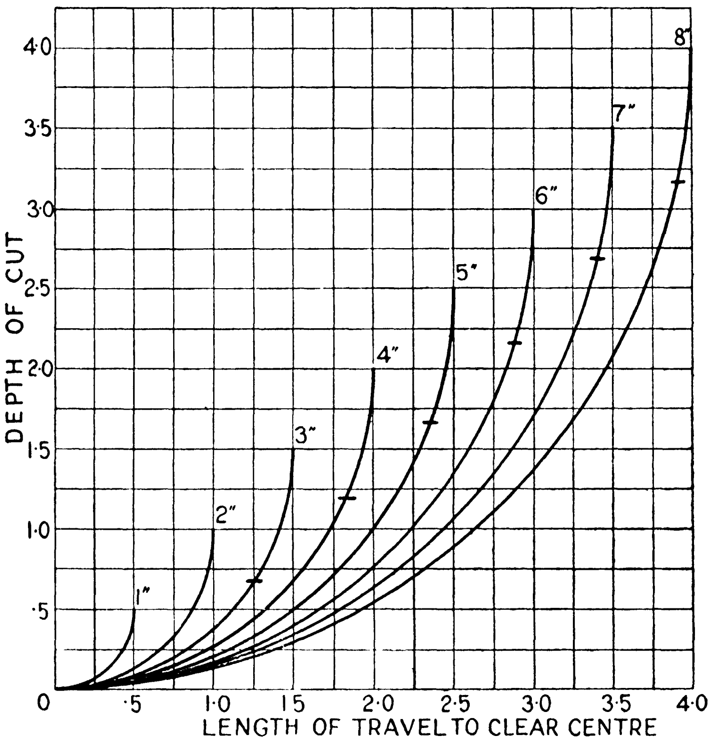


FIG. 17.

In milling, when cutting is done on the periphery of the cutter, the length of travel required is always in excess of the length of the face being machined owing to what is termed " centre travel." On the above diagram with the diameter of cutter and the amount of material to be removed known, the " centre travel " required can be read at sight. In making a diagram, reading is assisted if two colours are used for the radii, say red for odd numbers, black for even. The small horizontal line intersecting each radius represents the diameter of the clamping collars and indicates the greatest depth of cut which can be taken, or the height of obstacle which can be cleared with a cutter of that diameter.

the diagram on page 283, Fig. 17, which enables these amounts to be read off at sight. Incidentally, the greatest depth of cut which can be taken with a cutter of any diameter, can also be shewn, the diameter of the collars used for clamping the cutter in position on the cutter arbor being known. These depths are based on the use of clamping collars 1.625 inches diameter, but of course the diagram can be based on the use of collars of other diameters.

It is not sufficient, however, merely to know what length of travel is required for the milling of a job, diameter of cutter and depth of cut being shown. Seeing the length of traverse is affected by the diameter of cutter used, some discretion must be exercised as to what diameter of cutter is to be used. This is a matter which is often left entirely to the worker, but it is found sometimes that even the tool designer treats it as having no special importance. One really clever chief tool designer recently gave as his reason for designing large cutters, " economy of material, large cutters being capable of being cut and recut several times." If such economy of material had no counterbalancing effects, he would be correct, but there is little room for doubt on the matter that it has, and it is a question as to when " economy " becomes wasteful. Not only is the length of traverse unnecessarily increased by the use of unduly large cutters, as will be seen by the diagram, but the arc of contact being greater when cutting, more power is required to drive.

At the same time it is worthy of note that when the work is fed straight on to the cutters instead of across, the reverse is the case, both where the length of traverse and the arc of contact are concerned. The difference is not great, a point of some importance where the milling of bolts and nuts is concerned.

The number of cuts to be allowed for is dependent upon the requirements of the job, and the capacity of the machine, but, where a second cut is necessary, the amount of travel required in addition to the length of job will vary in accordance with the depth of cut. With quick rates of travel, particularly where the jobs are long, this factor may be negligible, but where slow travels are concerned the accumulated differences may be such as to justify notice. For example, if in removing .5 of an inch of material with a 4 inch diameter cutter, a second cut at the same setting were necessary to remove the " spring " of the arbor, the difference between the length of traverse of the two cuts would be approximately one inch.

The amount of travel per minute, possible, is also affected by the same considerations involved by the number of cuts, but the possibilities in this respect can often be improved, to a considerable extent, by ensuring the use of suitable cutting speeds, tight belts, sharp cutters and satisfactory clamping arrangements.

For the purpose of shewing how to build up an estimate for the rate of production for plain horizontal milling, the milling of the six faces of a plain steel block will be considered. The dimensions

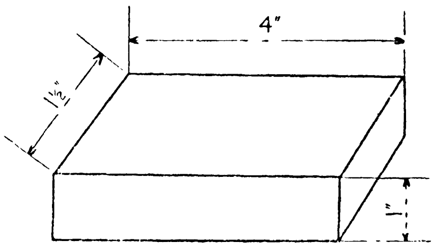
of the block—finished—are given on the sketch, and, as will be seen, it is assumed there is .0625 of an inch to be removed from each face. The pieces are presumed to be cut off, although it is not uncommon for the cutting-off of blocks of this kind to be included as a part of the first operation, a saw and a side-milling cutter being used.

The operations would be :

1. Straddle mill ends and 1 face.
2. ,, ,, width and opposite face.

BLOCK DISTANCE.

Part No. P12/24. Order No. 321.
Material, M.S. bar.



Pieces cut off. No. off 200.

Operation—Mill all faces.

Straddle mill length and 1 face	$\frac{3.6 \times 1}{1.5}$	$=2.4$
,, ,, width and opposite face	$\frac{6.1 \times 1}{1.5}$	$=4.06$
		6.46
Add 20 per cent. for contingencies		1.29
Set twice		1.5
Gauging done while machine running		...
		9.25

Estimated time, 9.25 minutes.

This is the kind of job for which the Lincoln type milling machine is specially designed. The work is such that gauging is practically unnecessary once the machine has been set, and, this being so, the operation becomes confined almost entirely to clamping pieces on the machine, running the cut over and removing. Not only has this led to the cheapening of the initial cost of the machine, but it has also made possible the simultaneous operation of several machines by one person, with a consequent saving of labour costs. With the operation referred to in the estimate, two or even three machines could be looked after by one worker, in which case one operation only would be done on one machine.

With hard material or heavy cutting where the amount of time required to run over the job is much greater than that of setting, the resultant economy can be a very material one. At the same time the fast rates of cutting possible to-day have altered the opportunities formerly available, and it is possible, in using more than one machine, by a disregard of the essential factors, actually to reduce output, machine hours rather than man hours being the criterion.

The factors which really govern the question are the setting and handling time, and these are fully discussed in Chapter XXI., the question affecting more than one type of machine.

In estimating the rate of production possible with plain horizontal milling operations, which are not repetition in their character, the difference will be found to be chiefly in the time required for setting and gauging. Without fixings, the setting may be more difficult, and, if more than one operation is to be performed, it is a question of altering the position of the cutter or the table rather than the setting of the job. Gauging of course becomes more necessary and additional cuts may be required owing to the uncertainty of setting cuts, without trial, that will give absolutely correct results. This depends very much on the nature of the job itself and the accuracy required. For example, much vertical milling is done solely for the purpose of obtaining flat faces, the relative position of such faces with others being negligible within wide limits. Gauging in these cases is of the simplest character, requiring little else but the laying on of a straight edge. On the other hand, an accurately milled face may be required, which must also be in a definite position relative with some other face; at once two factors are involved and both the gauging and the setting of cuts become more important. In such a case an additional cut will most likely have to be allowed for, to ensure the position required for the finished face being obtained. It may be that some millers may be able to get on without such an additional cut, but that would be an instance where, because of the ability of the worker, the estimate would be beaten, and this would be one of the results desired, which should be paid for as such.

The plain horizontal machine is also used for the milling of plain gear teeth, and straight cut milling cutters, and reamers, etc. The same methods of estimating obtain with these, but in addition to the ordinary setting of the job, the return of the table at the end of each cut and the "division" of the job to give the position for the next tooth needs to be allowed for. Excepting in the case of extra long jobs this will be found to take from 10 to 20 seconds and can be allowed for on that basis. Should abnormally long jobs be common and the return of the table take longer, a simple table can be built up if desired, allowing time for such return on a basis of distance to be traversed. See reference to start cuts on page 320.

The actual milling done on the universal milling machine is similar to that common to the plain horizontal machine but, whereas

the plain machine is designed to do chiefly " plain " work, the universal machine is provided with a swivelling table which enables angular work to be done, and with a train of wheels which, with the use of the dividing head, enables spiral cutting to be done; mechanical vertical feed is also provided. At the same time some of these provisions are now being made to the plain machines. So far as the estimating of rate of production is concerned these do not affect the issue. The time required for setting machines will be increased accordingly as the work involved becomes greater, but this can be suitably provided for.

With vertical milling machines, while operations of a more varied nature are involved, the method of estimating the rate of production is similar to that for horizontal milling. Where end milling is done, that is, cutting is done by the end of the cutter as distinct from the periphery, the minimum additional length of travel required to clear the cutter is one half of its diameter; dependent upon the nature of the job, it may be found necessary for the cutter to be run right over, and, in such a case, the minimum length of the cut would be the actual length of job plus the diameter of cutter, independently of what the depth of cut might be. Where side milling is concerned the operation, so far as length of traverse is involved, is identical with horizontal milling.

The decision as to what feed to use involves the consideration of more factors with vertical milling than with horizontal work. For ordinary horizontal work, the cutter arbor is supported at each end, which enables the cutter to offer a fairly rigid resistance to the cut, in accordance with the strength of the machine. With the vertical machine, excepting in the case of the larger machines, the end of the cutter is unsupported, and the feed to be used and also the number of cuts required must be dependent upon considerations not only of the class and amount of material to be removed, but also the diameter and length of cutter used, and of course the strength of the machine head. The possibilities will be found to vary within wide limits, and where side milling is concerned the results, measured in cost and accuracy of work combined, are often unsatisfactory.

No definite rates of feed or depth of cut can be laid down, but for a good quality of mild steel, where the amount of material removed is .125 of an inch, feeds of from 1 inch to 3 inches per minute can be obtained, according to width and the strength of the machine and cutter arbor. Records of the cutting of cast iron have little value, and when the cutting capacity of machines is given in connection with the cutting of cast iron, these can usually be taken as spectacular and as having little use as indicating the real cutting value of the machine. Brass can often be cut at a feed of 9 inches per minute and aluminium up to 20 inches.

Dealing with tabulation, the possibilities are considerable, owing to the fact that so much milling work is of a repetition character, and many interesting problems are to be encountered. One of the

simplest of the various classes of milling to be so handled, perhaps, is that of straddle milling. By straddle milling is meant the milling of the two ends or sides of one piece of material simultaneously, using "cheese" or side milling cutters; for example, the milling of squares or hexagons on bolts, or of a block to length. These operations usually are definite as to depth, the amount of material to be removed, and the kind of setting. Taking the milling of hexagon-headed bolts or nuts, whether the cutters are run across or directly on to the work, the sizes being known, the production rates can be tabulated to include or not the time for setting. Such a table can be made to cover more than one class of material, as, say, mild steel, brass or gunmetal. On the left-hand side of the table can be given the nominal bolt sizes, also the dimensions across flats and corners, this serving as an index for reference purposes in the case of variations in dimensions or of materials being met with. At the bottom of the table the amount of setting or handling time included for each size can be added for the purpose of considering the number of machines which may be worked at one time. In this connection reference to Chapter XXI. is advisable. If setting is not included the amount to be allowed for the various sizes can also be added at the bottom of the table. It is interesting to note that there is no appreciable difference in the time required for straddle milling hexagons and squares of the same size. The total travel required for a given "width across flats" is somewhat less in the case of squares, but the amount of material removed is greater, and may necessitate a reduction in feed. The same table can sometimes be used for both forms.

A similar table can be built up for the plain milling of rectangular faces and for the straddle milling of plain blocks.

In the latter case, the thickness of the job would be quoted at the side, and the length of job at the top. Alternatively, seeing different diameters of cutters may have to be used, to clear possibly some raised portion, actual lengths of travel could be quoted instead of lengths of job; that is, if the figures quoted covered the milling of a definite piece, say 1 inch thick and 3 inches long, and cutters of 4 inches diameter were used, the respective dimension would be given as 3 inches, but if the length of the actual travel were quoted, then the amount would be 4.75 inches, although the time in each case would be the same. The course recommended is that of providing for the common-place as being most often required, leaving special features to be handled as they arise. Tables which can be construed as allowing for the use of cutters of unsuitable size, however, may become an encouragement to that end, and once it became known in the shops that the additional travel incidental to large cutters was allowed for in the job rates, new jobs to be estimated would be likely to be started up with the use of cutters which were too large. In a table of this kind, arrangements could be made to allow times for the removal of different amounts of material as well as for various thicknesses and lengths, although it

MILL HEXAGON—STRADDLE. (No. 8)

G. = GUNMETAL. S. = MILD STEEL.

Dimensions.			Thickness.																						Screw-on Settings.
Bolt.	Across.		.25		.375		.5		.625		.75		.875		1.0		1.125		1.25		1.375		1.5		
	Flats.	Corners.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	
.25	.525	.606	1.0	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1
.375	.709	.819	1.2	2.5	1.4	3.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1
.5	.919	1.061	1.4	3.0	1.6	3.5	1.8	4.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1
.625	1.1	1.27	1.7	3.5	1.9	4.0	2.1	4.5	2.3	5.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.1
.75	1.301	1.503	2.0	4.0	2.2	4.5	2.4	5.0	2.6	5.5	2.8	6.0	—	—	—	—	—	—	—	—	—	—	—	—	.1
.875	1.48	1.709	2.3	4.5	2.5	5.0	2.7	5.5	2.9	6.0	3.1	6.5	3.3	7.0	—	—	—	—	—	—	—	—	—	—	.2
1.0	1.67	1.929	2.7	5.0	2.9	5.5	3.1	6.0	3.3	6.5	3.5	7.0	3.7	7.5	3.9	8.0	—	—	—	—	—	—	—	—	.2
1.125	1.86	2.148	3.0	5.5	3.2	6.0	3.4	6.5	3.6	7.0	3.8	7.5	4.0	8.0	4.2	8.7	4.4	9.3	—	—	—	—	—	—	.2
1.25	2.05	2.368	3.3	6.0	3.5	6.5	3.7	7.0	3.9	7.5	4.1	8.0	4.3	8.7	4.5	9.3	4.7	10.0	4.9	10.7	—	—	—	—	.2
1.375	2.214	2.557	3.7	6.5	3.9	7.0	4.1	7.5	4.3	8.0	4.5	8.7	4.7	9.3	4.9	10.0	5.1	10.7	5.3	11.3	5.5	12.0	—	—	.2
1.5	2.41	2.784	4.0	7.0	4.2	7.5	4.4	8.0	4.6	8.7	4.8	9.3	5.0	10.0	5.2	10.7	5.4	11.3	5.6	12.0	5.8	12.7	6.0	13.3	.2

Setting included as for bolts. For nuts or screw-on settings allow as side column.

would be wise to specify under what conditions the removal of these varying amounts should be treated as representing normal working.

In the tabulation of the time required for milling rectangular faces the question of the number of cuts required must be considered, and these should be stated so that the conditions under which the table could be applied would be known. The remarks previously made regarding setting would also apply here, although, seeing plain milling jobs are usually held in the vice, there would appear to be no good reason why setting should not be definitely included; if desired, the amount could be quoted at the bottom of or below the table. A form as shewn below would be found suitable.

MILLING PLAIN FACES. (No. 9)

G. = GUNMETAL. S. = MILD STEEL.

Width of Face.	Length of Face.													
	·5		1		2		3		4		5		6	
	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.	G.	S.
·5														
·75														
1·0														
1·5														

The time for milling teeth in milling cutters and reamers can also be conveniently tabulated. Tables can be built up to cover cutters with teeth of a definite depth or on the basis of the rate of travel per minute possible. The better plan is to specify depth of tooth and rate of travel, and, when the latter cannot be obtained, to enquire as to the reason, making a special allowance if required. Seeing the number of teeth called for in cutters varies considerably, it may be found an advantage to extend the tables as to their range in that connection, while restricting the intermediate references.

On the next page, a table is given in which times are quoted for 4 to 72 teeth rising in fours—the intermediate numbers being provided for by the figures in the end column headed "plus or minus per tooth." Thus if a cutter had 22 teeth, the time for the requisite length would be taken under 20 at the top of the column and the amount in the end column, on the appropriate line, would be doubled and added. If the length of travel required to cut each tooth were 4.75 inches the time to complete would be 117 minutes plus 11.8 minutes, a total of 128.8 minutes. Tables for different depths and types of teeth and lengths of travel can be arranged as required.

It should be pointed out that there may be a difference in the travel required for a milling cutter tooth and a reamer tooth of a given length. In the ordinary way, with a milling cutter tooth, the cut must be run straight over, thereby involving "centre travel," while with the reamer it frequently happens that the cut must be run into a partially cleared recess, the length of tooth becoming the length of travel. In this connection, if centre travel be included in the table, and the amount be separately stated, the requisite deduction would enable the correct time to be given. Thus, if in the table, and for a cutter 4 inches long, .5 inches had been allowed to cover centre travel, the actual length of the cut allowed for would be 4½ inches. If the actual length of the reamer tooth cut were 4 inches, the time for same should be taken from the 3½ inch column. In the sample table given below, it will be noted that the basis is the length of travel, not length of tooth.

MILLING TEETH (No. 10)

Milling Cutters. Reamers, Etc.

Basis of Table. 1″ Travel per Minute. Setting of Job not Included

Length of Travel.	Number of Teeth.																		Plus or Minus per Tooth.
	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	
.5	3.4	7.1	11	14	18	22	25	29	33	36	40	44	47	51	55	58	62	66	.92
.75	4.6	9.4	14	19	24	29	34	38	43	48	53	58	63	67	72	77	82	87	1.21
1.0	5.7	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	1.5
1.25	6.9	14	21	28	36	43	50	57	64	71	79	86	93	100	107	114	122	129	1.79
1.5	8.1	16	25	33	41	50	58	66	75	83	91	100	108	116	125	133	141	150	2.08
1.75	9.2	19	28	38	47	57	66	76	85	95	104	114	123	133	142	152	161	171	2.38
2.0	10	21	32	42	53	64	74	85	96	106	117	128	138	149	160	170	181	192	2.67
2.25	12	23	35	47	59	71	83	94	106	118	130	142	154	165	177	189	201	213	2.96
2.5	13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	3.25
2.75	14	28	42	56	71	85	99	113	127	141	156	170	184	198	212	226	241	254	3.54
3.0	15	30	46	61	76	92	107	122	138	153	168	184	199	214	230	245	260	276	3.83
3.25	16	33	49	66	82	99	115	132	148	165	181	198	214	231	247	264	280	297	4.13
3.5	17	35	53	70	88	106	123	141	159	176	194	212	229	247	265	282	300	318	4.42
3.75	19	37	56	75	94	113	132	150	169	188	207	226	245	263	282	301	320	339	4.71
4.0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	5.00
4.25	21	42	63	84	106	127	148	169	190	211	233	254	275	296	317	338	360	381	5.29
4.5	22	44	67	89	111	134	156	178	201	223	245	268	290	312	335	357	379	402	5.58
4.75	23	46	70	94	117	141	164	188	211	235	258	282	305	329	352	376	399	423	5.88
5.0	24	49	74	98	123	148	172	197	222	246	271	296	320	345	370	394	419	444	6.17
5.25	26	51	77	103	129	155	181	206	232	258	284	310	336	361	387	413	439	465	6.46
5.5	27	54	81	108	135	162	189	216	243	270	297	324	351	378	405	432	459	486	6.75
5.75	28	56	84	112	141	169	197	225	253	281	310	338	366	394	422	450	479	507	7.04
6.0	29	58	88	117	146	176	205	234	264	293	322	352	381	410	440	469	498	528	7.33
6.25	30	61	91	122	152	183	213	244	274	305	335	366	396	427	457	488	518	549	7.63
6.5	31	63	95	126	158	190	221	253	285	316	347	380	412	443	475	506	538	570	7 92

For setting allow: solid cutters, 1½ minutes; bored cutters, 3 minutes.

In the tabulation of the times for the milling of gear teeth, is to be found a somewhat difficult problem. The numerous pitches, the numbers of teeth, the lengths of teeth, the incidence of cutter diameter and of centre travel, the capacities of machines and the classes of material used would make complete tabulation a most bulky job, and one probably not justifying the doing, excepting in a gear-cutting works. The problem can be got over, however, in

some measure by reducing the variable factors to a common unit. These are length of tooth plus centre travel and number of teeth, and if these two be multiplied, and the product be given in inches, then the time per inch of travel for the various pitches, material, and finishes being known, a ready method of tabulation is made possible.

A form of table is shewn on the next page from which it will be seen that in the first portion are given particulars of the various pitches—diametral and circular—the depths of tooth, and the appropriate centre travel. In the second portion, in the respective columns, is quoted the time in minutes for traversing one inch for the pitches quoted in the preceding columns. Those columns, three in number, are shewn to cover three materials only, but it is possible, of course, for these to be increased to cover any number of different kinds of material.

The estimate for the tabulation is arrived at in precisely the same manner as other milling estimates; only in this case one inch traverse being the unit of reference the time estimated must be for one inch only, the addition for cutting contingencies being made according to conditions.

In connection with the use of automatic gear cutters of the milling type, there is no difference in the method of estimating. The return movements and the divisions are much more quickly made on the automatic machine than on the plain milling or universal machine, and these rates can, of course, be included in the table. Thus if 3 inches per minute be the rate of feed, the cutting time per inch will be .33 minutes, and if 10 per cent. be added to cover contingencies the total time per inch of travel will be .366 minutes. This factor being embodied in the table an estimate for the cutting on an automatic machine of 40 teeth, 1.5 inches long, with an assumed centre travel of 1 inch, would be as follows:

	Minutes.
Mill teeth 40 × 2.5 × .366 - - - - - - -	= 36.6
Change tooth to tooth and start cuts 40 × .06 - -	= 2.4
Change and set job in machine - - - - -	= 3.0
Estimated time - - - - - - -	= 42.0

If two classes of finish are required, as, say, one cut and two cuts, separate tables will be needed, excepting the cuts be split in such a manner that the same feed per minute is used for each; then the time per inch given in the "one cut table" could be doubled; even then the difference in the centre travel required would need to be noted and allowed for. "Centre travel" columns could be provided for roughing and finishing cuts. So much depends upon the materials, methods and cutters used that tables must be built up in accordance therewith.

In connection with vertical milling, opportunities for special job tabulation are not so common. There are, however, in some works

MILLING PLAIN GEAR TEETH. (No. 11)

Pitch and Centre Travel Details.								Pitch and Time Details.							
Pitch.		Tooth Depth.	Centre Travel.	Pitch.		Tooth Depth.	Centre Travel.	Pitch.			Minutes per Inch of Travel.	Pitch.			Minutes per Inch of Travel.
Dia-metral.	Circular.			Dia-metral.	Circular.			G.M.	C.I.	M.S.		G.M.	C.I.	M.S.	
$1\frac{1}{4}$	2.513	1.726		12	.2618	.1798	.8	—	—	—		5	7	10	.4
$1\frac{1}{2}$	2.094	1.438		14	.2244	.1541	.75	—	—	$1\frac{1}{4}$		6	8	12	.369
$1\frac{3}{4}$	1.795	1.233		16	.1963	.1348	.7	—	—	$1\frac{1}{2}$		7	9	14	.343
2	1.571	1.079		18	.1745	.1198	.65	—	—	$1\frac{3}{4}$		8	10	16	.32
$2\frac{1}{4}$	1.396	.959		20	.1571	.1079	.6	—	$1\frac{1}{2}$	2		9	12	18	.30
$2\frac{1}{2}$	1.257	.863		22	.1428	.0980	.56	—	$1\frac{1}{2}$	$2\frac{1}{4}$		10	—	20	.285
$2\frac{3}{4}$	1.142	.784		24	.1309	.0898	.53	$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$		—	14	22	.267
3	1.047	.719		26	.1208	.0829	.52	—	—	$2\frac{3}{4}$		12	16	24	.253
$3\frac{1}{2}$	.898	.616		28	.1122	.0770	.5	$1\frac{1}{2}$	2	3		—	—	26	.24
4	.785	.539		30	.1047	.0719	.48	$1\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{1}{2}$		14	18	28	.228
$4\frac{1}{2}$	.698	.479		32	.0982	.0674	.46	2	$2\frac{1}{2}$	4		—	20	30	.218
5	.628	.431		34	.0924	.0634	.45	$2\frac{1}{4}$	3	$4\frac{1}{2}$		16	—	32	.209
$5\frac{1}{2}$	.571	.392		36	.0873	.0599	.44	$2\frac{1}{2}$	—	5		—	22	34	.2
6	.524	.360		38	.0827	.0568	.43	$2\frac{3}{4}$	$3\frac{1}{2}$	$5\frac{1}{2}$		18	24	36	.192
7	.449	.308		40	.0785	.0539	.42	3	4	6		—	—	38	—
8	.393	.267		42	.0748	.0514	.41	$3\frac{1}{2}$	$4\frac{1}{2}$	7		20	26	40	—
9	.349	.240		44	.0714	.0490	.40	4	$5\frac{1}{2}$	8		22	30	44	—
10	.314	.216		48	.0654	.0449	—	$4\frac{1}{2}$	6	9		24	32	48	—

Est. = (length of tooth + centre travel) × No. of teeth × min. per inch.
Divisions and start cuts. Allow : Automatic machine, .06 minute each ; Hand .33 minute each.
Setting : Solid pieces, $1\frac{1}{2}$ minutes ; Mandrel jobs, 3 minutes.

some classes of work which lend themselves to this. One of these is the milling of flats on spindles and shafts. It may be that one or two flats are required, or a square or hexagon. While separate tables can be made out for each of these requirements, one table can be used to cover most, if not all, ordinary jobs.

To do this, estimates are required for milling one flat in lengths varying from 1 inch to the greatest number likely to be required. In the sample table on the next page this is shewn as starting at 1 inch and, in graded steps, going up to 36 inches. In the columns at the left-hand side are given the dimensions across flats and corners of squares and hexagons of various sizes, but it will be noted the squares of one size are not placed on the same line as the hexagon of the same size. The reason for this is as follows. The dimension across the corners of a 1 inch square is 1.414 inches; consequently the amount of material to be removed from each side is equal to one half of the difference—.207 inches, the cut being 1 inch wide. This has been taken as being equivalent to the milling of a 2 inch hexagon. With a 2 inch hexagon, the measurement across the corners is shewn to be 2.31 inches, and one half of the difference being .155 inches, that constitutes the amount of material to be removed, the width of face left being 1.155 inches; a little less material to remove in depth, a little wider face to be machined.

To allow for the additional work consequent to the increase in the number of flats, the plus column on the right-hand side of the table is arranged to give this, the amount on the appropriate line to be multiplied by the number of additional sides called for. In this column the squaring of the flats at the end, and of the requisite divisions, start cuts and gauging are allowed for. In another column will be found the time required per inch of flat to cover lengths not quoted; thus if 13 inches of flat are to be milled, the time required will be found on the appropriate line under 12, to which, on the same line, the amount for 1 inch would need to be added. Then from the table the estimated time for milling flats of the same total length, but to make up different shapes, would be obtained as shewn below, the setting of the job in the machine not being included. For example, a spindle milled square, 3 inches in length would have a total length of flat of 12 inches, 3 inches × by 4 sides.

Total Length of Flats.	No. of Sides.	Estimated Time.		
		Milling Flats.	Squaring Corners, etc.	Total.
12″	1	20.4	—	20.4
12″	2	20.4	2.6	23.0
12″	4	20.4	7.8	28.2
12″	6	20.4	13.0	33.4

END MILL FLATS ON SPINDLES. (No. 12)

MATERIAL—MILD STEEL.

Square.		Hexagon.		Length of Flat.																		Plus Per.	
Flats.	Corners.	Flats.	Corners.	1	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	Inch.	Additional Side.
—	—	.25	.289	1.72	2.62	4.42	6.22	8.02	9.82	11.6	13.4	15.2	17.0	18.8	20.6	22.4	—	—	—	—	—	—	.90	1.2
.25	.354	.5	.577	1.94	2.90	4.82	6.74	8.65	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.8	31.7	33.6	35.1	.96	1.3
.375	.530	.75	.866	2.18	3.20	5.25	7.29	9.34	11.4	13.4	15.5	17.5	19.6	21.6	23.7	25.7	27.8	29.8	31.8	33.9	35.9	38.0	1.02	1.5
.5	.707	1.0	1.155	2.58	3.68	5.88	8.08	10.3	12.5	14.7	16.9	19.1	21.3	23.5	25.7	27.9	30.1	32.3	34.5	36.7	38.9	41.1	1.10	1.7
.625	.884	1.25	1.443	3.08	4.28	6.66	9.04	11.4	13.8	16.2	18.6	20.9	23.3	25.7	28.1	30.5	32.9	35.2	37.6	40.0	42.4	44.8	1.19	2.2
.75	1.061	1.5	1.732	3.63	4.93	7.50	10.1	12.7	15.3	17.9	20.5	23.1	25.7	28.3	30.9	33.5	36.1	38.7	41.3	43.9	46.5	49.1	1.30	2.6
.875	1.237	1.75	2.021	4.12	5.48	8.21	10.9	13.7	16.4	19.1	21.8	24.6	27.3	30.0	32.7	35.5	38.2	40.9	43.6	46.4	49.1	51.8	1.36	3.0
1.0	1.414	2.0	2.309	4.62	6.05	8.92	11.8	14.7	17.5	20.4	23.3	26.1	29.0	31.9	34.7	37.6	40.5	43.3	46.2	49.1	51.9	54.8	1.43	2.6
1.125	1.591	2.25	2.598	5.12	6.63	9.65	12.7	15.7	18.7	21.7	24.8	27.8	30.8	33.8	36.9	39.9	42.9	45.9	49.0	52.0	55.0	58.0	1.51	3.0
1.25	1.768	2.5	2.887	5.66	7.26	10.5	13.7	16.9	20.0	23.3	26.5	29.7	32.9	36.1	39.3	42.5	45.7	48.9	52.1	55.3	59.5	61.7	1.60	3.8
1.375	1.945	2.75	3.175	6.23	7.93	11.3	14.7	18.1	21.5	24.9	28.3	31.7	35.1	38.5	41.9	45.3	48.7	52.1	55.5	58.9	62.3	65.7	1.70	4.2
1.5	2.121	3.0	3.464	6.93	8.74	12.4	16.0	19.6	23.3	26.9	30.5	34.1	37.8	41.4	45.0	48.7	52.3	55.9	59.5	63.2	66.8	70.4	1.81	4.8
1.625	2.298	3.25	3.753	7.69	9.63	13.5	17.4	21.3	25.2	29.1	33.0	36.9	40.8	44.7	48.6	52.4	56.3	60.2	64.1	68.0	71.9	75.8	1.95	5.4
1.75	2.475	3.5	4.041	8.54	10.6	14.8	19.0	23.2	27.4	31.6	35.8	40.0	44.2	48.4	52.6	56.8	61.0	65.2	69.4	73.6	77.8	82.0	2.10	6.0
1.875	2.652	3.75	4.330	9.51	11.8	16.4	20.9	25.5	30.0	34.6	39.2	43.7	48.3	52.9	57.4	62.0	66.6	71.1	75.7	80.2	84.8	89.4	2.28	6.8
2.0	2.828	4.0	4.619	10.7	13.2	18.2	23.2	28.2	33.2	38.2	43.2	48.2	53.2	58.2	63.2	68.5	73.2	78.2	83.2	88.2	93.2	98.2	2.50	7.6

When length of flat is less than one-half the size " across," allow time per side from end column only. Setting is not included above. Allow plain spindle jobs 1½ minutes, mandrel jobs 3 minutes.

It should be remembered that the time required for finishing off the end of the first flat—removing the radius left by the cutter and squaring up—is included in the estimate for one flat, and that the additional time necessary for milling the same length of flat when apportioned over 4 sides consists of that required to divide and to square up 3 ends only, and for hexagons—5 ends only.

A similar table can be built up for the milling of plain faces, different lengths and widths being allowed for. If gauging and divisions, etc., are given separately from the cutting time, then, by the use of suitable factors, a table can be arranged to cover all classes of material being handled. When the milling of levers is a common operation, a table can be conveniently arranged, on the basis of sizes or in accordance with individual dimensions for the milling of the back, the front, the sides, the boss and the radii.

Profile milling can be dealt with on similar lines, but in this connection, seeing mechanical feed is not, usually, provided, the class of material and the amount to be removed, both in the depth of cut and of the thickness of the profiled face on which the cut is being taken, become of more than ordinary importance. The best practice is to test the machines in use for their material removing capacity, using men, youths or girls for the test, as the case may be, and to build up a table on the basis of thickness of profile and the amount of material to be removed. Such a table can be constructed on the following lines, in connection with which, factors for the various materials can be arranged as found necessary.

PROFILING TABLE. (No. 13)

Thickness.	Material to be Removed.							
	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$
$\frac{1}{8}$								
$\frac{3}{16}$								
$\frac{1}{4}$								
$\frac{5}{16}$								

There are many classes of work which have not been touched upon. In principle, however, the methods of estimating, as of doing the work itself, are similar, and if the practice of analysis be efficiently followed it will be found that the greatest portion of the milling work can be suitably handled.

Hobbing. Hobbing might be described as a form of milling operation. Its use is confined to the machining of gear and worm teeth, for which it is an economical process; for worm wheels no other method is commercially possible. With worm wheels, the hob is sometimes fed directly towards the centre, there being no movement across the wheel; in other cases the hob is set at the

right distance from the centre of the worm wheel and then traversed across. When cutting pinion teeth the hob is set in the correct position and fed across the teeth.

The formula by which the cutting time can be obtained is as follows:

$$\text{Cutting time} = \frac{\text{length of travel}}{\text{feed per minute}}.$$

The rate of feed, however, cannot be fixed for wheels of a given size of tooth; the considerations in this respect are size and number of teeth. Thus if two wheels be taken with 20 and 60 teeth respectively, of the same size, the feed per minute used with the latter would be just one third of that used with the former, because the revolutions of the wheel itself would be at the rate of 1 in 3 for the smaller wheel. In such a case the feed requires to be stated as x amount per tooth of a given pitch, that factor to be divided by the number of teeth in the wheel. Alternatively, the feed can be stated as x amount per revolution of the job, the number of or the time for which can be obtained by the use of the following formula:

Time per revolution of job

$$= \frac{\text{number of teeth}}{\text{revolutions of hob per minute} \times \text{number of starts}}.$$

Revolutions of job per minute

$$= \frac{\text{revolutions of hob} \times \text{number of starts}}{\text{number of teeth}}.$$

Then, with the feed per revolution of the job used as the basis, the cutting time would be obtained thus:

$$\text{Cutting time} = \frac{\text{number of teeth} \times \text{depth of tooth}}{\text{revs. of hob} \times \text{feed per minute}},$$

and the time for cutting the teeth in a worm wheel having 60 teeth when the depth is .5 of an inch, the feed per revolution, .02 of an inch, and the revolutions of hob are 40 per minute, will be obtained as follows:

$$\text{Cutting time} = \frac{60}{40} \times \frac{\cdot 5}{.02} = 37\cdot 5 \text{ minutes.}$$

When the time per revolution of the job is used the calculation will be shewn as below:

$$\text{Cutting time} = \frac{\cdot 5}{.02} \div \frac{40}{60} = 37\cdot 5 \text{ minutes.}$$

Dealt with as a factor per tooth this would be .625 minutes per tooth. Factors of this kind can be tabulated for the various tooth sizes and materials and also to allow for the influence of the angle of the spiral or worm.

With the hobbing of spur gears, the formula is similar, but centre travel must be allowed for as in ordinary milling. Apart from this the procedure is the same as with worm wheels.

When the hob is traversed across the worm wheel, a coarse feed can be used until the full thread of the hob is engaged and, also, when the hob is past the centre of the worm wheel. The formula is similar to that used for other hobbing.

CHAPTER XXVIII

PRODUCTION ESTIMATING—LATHE WORK

LATHE work, turning, as it is usually termed, is perhaps the most varied of all the machining processes to be found in engineering manufacture. It calls for more delicate handling in the setting of cuts than other processes, because, by virtue of the work being revolved, cutting is done on both sides of the centre, the reduction in diameter being equal to twice the depth of cut. Further, it is customary, excepting where roughing only is concerned or where grinding is resorted to, for lathe work to be finished so closely to size and with so fine a surface that hand finishing in the shape of filing and scraping is not necessary. There are exceptions, as with the scraping of bearings, but when this is required it is a matter of easing "hard" places rather than of deliberately arranging to scrape the whole of the bearing surface.

In addition to the fine finish obtained in lathe work, both for appearance and size, the varied nature of the operations carried out in connection therewith includes, in addition to plain turning, with its different types of tools and finishes, drilling, boring and the cutting of threads and worms of all kinds. These go to make the acquirement of an all-round knowledge of turning one of the most difficult and lengthy to obtain, and it is logical that the varied nature of the operations incidental to lathe work, and of the class and sizes of work handled, will be reflected in estimating the rate of production. This is the case, although the influence is felt in the need for more data rather than in a variation of the formulae used, and for a wider experience of the production estimator than is required in dealing similarly with other machining processes.

If the general recommendations made in Chapter XXIII. have been observed, the question of estimating becomes one of the application of the practical knowledge of the production estimator, guided by such data and instructions as have been passed on to him. In view of the varied nature of the operations performed on lathes, it is desirable to analyze these, and to indicate on what lines data should be collected. Lathe work, in the ordinary way, falls naturally into two main divisions: external and internal work. Under external work is found plain turning, roughing and

finishing; facing, parting-off, the cutting of vee, square and other types of screw threads, and worms. With internal work, the operations are chiefly drilling, boring, and the cutting of the various kinds of threads.

As well as with the varied nature of the operations performed, lathe work—turning—varies in size perhaps as widely as in any engineering process in use. There is the watchmaker's spindle and the marine shaft; the length of the one less than 1 inch, while the other may exceed 60 feet in length; the diameters turned vary from .1 of an inch to upwards of 30 feet, but this makes no difference to the process or to the method of estimating. As with most processes, turning involves setting, cutting and handling, and this obtains whether the work be large or small.

Setting is a somewhat variable process. In some cases this is of the simplest character, as with centre work and most of the chuck work, but one complication is met with which is peculiar to lathe work, the need for balancing. Due to the work being revolved, it is necessary that pieces shall be so balanced that there is no heavy side, otherwise the work done will not be round. Balance weights can be readily fixed, but it is advisable that the time allowance for balancing, when it is required, should be made a separate item in the estimate and kept distinct from setting.

The setting of bar blanks is more quickly done than forgings or castings and, where the operations are short, this will require special recognition. The use of self-centering chucks enables the setting of regular shaped pieces to be done more quickly than does the independent four-jaw chuck. At the same time, it may be found that the better grip of the latter, enabling heavier cuts to be taken, renders its use the more desirable for other than light work. For pieces of irregular shape, of course, there is no alternative. In centre work where mechanical traverse can be used, and where there is a quantity to be machined, two carriers should be used, the one should be removed from the completed piece and be fixed on the next while cutting is proceeding, and the estimate should be based on this being done.

The most important part of an estimate for lathe work, however, is the cutting time, which in the majority of cases forms the greater portion of the estimate. Cutting time is estimated by the use of the following formula:

$$\text{Cutting time} = \frac{\text{length of traverse} \times \text{number of cuts} \times \text{feeds per inch}}{\text{revolutions per minute}}.$$

In the question of revolutions per minute, a factor exists which is not found except with turning, namely, that as the tool is fed toward the centre, although the revolutions per minute are not affected, the effective cutting speed is reduced. Where the facing of surfaces of large diameter is concerned, this must be taken into consideration. Some headstocks are designed with "drives" which provide a constant cutting speed, the revolutions being

automatically increased as the tool is fed to the centre. For large surfaces or, in fact, for comparatively small surfaces where large numbers are concerned, such a drive can be most economical in its results.

In passing, however, it might be mentioned that it is not uncommon for "constant speed" drives to be so used that the speed obtained is not constant. Actually constant speed can be obtained only when the tool is set in one position relative with that of the drive. This fact is not always recognized, and it is not uncommon to find that tools are set quite independently of this position, the result being variable cutting speeds.

As a matter of fact, a "constant speed" drive can give but one constant speed ; that is, if the drive with the tool in the requisite position gives a peripheral speed of 60 feet per minute for the diameters within its range, a constant speed at any other rate cannot be obtained excepting by a charge of pulley or by the provision of a step cone or a variable speed motor. It is possible, and has happened that, due to the wrong position in which tools have been set, the cutting speed has been increased at such a rate that the edges of the tools have been destroyed. The varying value of circumference as regards peripheral speed is the reason for this. A machine fitted with a constant speed drive is really provided with automatic changes of speed for every diameter within its range, and it follows that the tool should be so set that its position coincides with the indexed position on the drive. That is, if the tool is cutting at 12 inches diameter, the speed obtained should be the number of revolutions designed for 12 inches diameter. The following figures shew the result, in peripheral speed, of setting the tool in the right and wrong positions :

Diameter in inches - - -	6	12	18	24	30	36
Revolutions required to give peripheral speed of 60 feet -	38.2	19.1	12.7	9.5	7.6	6.4
Peripheral speed at revolutions quoted ; tool set in correct position - - - - -	60	60	60	60	60	60
Peripheral speed when tool set to cut at 6 in. diameter in the 12 in. position - - -	30	40	45	48	50	—
Peripheral speed when tool set to cut at 12 in. diameter in the 6 in. position - - -	—	120	90	80	75	72

The significance of these figures will be appreciated and, where batteries of such machines are working, attention to the point made will be justified.

Where the "constant speed drive" is in regular use the difference in actual output compared with that which is possible, consequent to the neglect of the necessity to provide an appropriate cutting speed in the first place, and of the failure to observe the correct

position of the tool in relation to that of the drive in the second, can be considerable, and would upset estimates accordingly.

It is the more common experience, however, to find that, for ordinary work, lathes are provided either with the step cone or an all-geared headstock, with which to obtain changes of speed, and although the number of speed changes now provided is very much more satisfactory than in the years gone by, the avoidance of "steps" is practically impossible.

Where estimating is concerned it is difficult to recognize these steps; if all the machines of one type in use were made by one manufacturer something could be done in this respect, because all steps would be alike; although even here, seeing the removal of material is a combination of feed and speed, it is doubtful if it is of sufficient importance to justify the attempt. The better plan, certainly the simpler, is to estimate on the basis of a suitable cutting speed for the major diameter, where rough turning is concerned, stepping down as the material removed justifies. In the majority of cases the reduction in diameter which takes place in roughing is not sufficient to call for this change to be made, and the turner is likely to increase the depth of his cut as a compensation for, and made possible by, the reduced cutting speed.

When facing is involved the change of speed becomes of greater importance, and the most convenient method is to adopt an average mean speed for estimating rather than to estimate each step. Thus, if a 40 inch face were being machined, and a cutting speed of 60 feet per minute were desired, there would be scope for 4 increases in revolutions per minute, which would be made by the turner in the ordinary course of events; for estimating purposes, however, if a mean were taken of the highest and lowest steps, and the estimate were taken out at this rate, the result in time would be the same as though the estimate followed the steps made. Thus, if 10 inches were the lowest diameter at which speed was increased, the use of the mean of 40 and 10—25 inches—would give the same cutting time as though the estimate were taken out separately for diameters of 40, 30, 20 and 10 inches.

In dealing with the cutting speed to be used on large pieces, especially when cutting is being done at or near the centre, it is sometimes found that to obtain that speed at which the material should be cut, the revolutions required per minute would be greater than those at which the job could be safely run. This is the experience sometimes with vertical lathes, being particularly so when the job itself is irregular in shape. The estimate must then be taken out on the basis of the number of revolutions which can be used.

It needs to be borne in mind that the cutting speeds used, and used with efficiency, vary with the practice of the man as well as with the material used. The speeds, feeds, and depths of cut taken by different turners are often widely different, although the results may be similar. Under these circumstances, excepting all

the conditions are fixed and all the tools used are accurately ground to a standard angle and form, it is a mistake to insist upon the use of any one minimum, whether of speed, feed or depth of cut. As far as materials are concerned, some mild steels can be cut more readily at the rate of 120 feet per minute than can others at 40 feet; finishing, however, can usually be done at about one half the speed of roughing. With lathe work perhaps more than with other processes the practice referred to on page 240 will repay itself. It is most helpful to the turner if the speeds of lathes are counted, and the number of revolutions required to give suitable roughing and finishing speeds be stated on a card placed in a convenient position. If this is not done the turner must always guess or ascertain by trial what is a suitable speed to use, and in experimenting, his tool can quite easily be spoiled. Further, a check by foreman or manager means counting the revolutions, checking the diameter of the material being turned, and calculating the speed before the facts can be known, leave alone arriving at an opinion. In the absence of this provision standards of cutting speeds, generally speaking, are not considered.

The depth of cut and the feed to be used can also be specified, for different diameters and lengths of job, for different sizes of lathes and for different materials. These are certainly needed for the production estimator, if his work is to be consistent with that of others, and there is no apparent reason why this information should not be issued to the shops for the guidance of the workers. It has an educational value which is very real. A table such as the following will be of use :

TURNING DATA—LATHE. (No. 14)

Material.	Feet per Minute.		Rough Turning.					
	Rough.	Finish.	Dia. in Inches.	Depth of Cut.	Feeds per Inch.	Dia. in Inches.	Depth of Cut.	Feeds per Inch.
Mild Steel A. -	120	60	½	.03	40	3	·3	20
Mild Steel B. -	50	30	1	.08	32	4	·35	16
Steel Casting -	40	25	1½	.12	24	5	·4	16
Cast Iron - -	50	25	2	.18	24	6	·45	12
Tool Steel - -	30	15	2½	.25	20	7	·5	12
Gun Metal - -	100	60						
Soft Brass - -	150	90						

For Finishing.	Allow 1 cut, class 1 finish. ,, 2 cuts, ,, 2 ,,									
Dia.	½	1	1½	2	2½	3	4	5	6	7
Feeds per Inch.	64	48	32	32	24	16	12	10	8	6

But little needs to be said with reference to plain turning, whatever may be its size. For the production estimator to be an efficient turner himself is not only necessary, but is often found to be of

great value in enabling suggestions to be made to turners as the estimates are taken out. In this connection, some firms make no attempt to teach their apprentices, and apprentices often grow up with a very unsatisfactory knowledge of even the rudiments of turning, as, for example, with screw-cutting, and where straightening is concerned the practices followed are often most deplorable. It is good, however, to be able to say this state of things is being remedied.

Every cutting operation on the lathe can be estimated, whether it be turning or boring plain diameters, screw-cutting or facing. For the different types of tools used, feeds, if not speeds, will vary; for example, the facing of shoulders, as on shafts, must often be done with a pointed tool so that a square corner shall be left. In such a case the feeds will be as fine sometimes as 100 to the inch, while the facing of the ends of small shafts, etc., will be as low as 64 to the inch. On the other hand, where an ordinary turning tool can be applied the feeds often used are as coarse as 4 to the inch; large shafts are often "scraped" with feeds of 2 to the inch.

In some works, diameters are expected to be turned within tolerances of .001 of an inch without the use of a file. The practice is quite often a nominal one, and surreptitious filing is commonly done in order to overcome irregularities of size, which may reflect a faulty lathe rather than an inefficient turner. Where this is the aim, and there is something to be said in its favour, then, with accurate work, at least one extra finishing cut is required, or an extended period of polishing, for the purpose of obtaining the degree of accuracy specified.

The question of preparing for "running" or stationary steadying stays, when long shafts or spindles are being turned, becomes a matter of plain estimating, and time must be allowed for this as required. It is useful to have some rule which will indicate when a stationary stay becomes necessary, and further, when a "running" stay is required. When the length of work exceeds 12 diameters, difficulty begins to be experienced, and when 16 diameters are exceeded a stationary stay is usually necessary. The change from the use of the stationary stay to that of the running type is oft-times a matter of preference on the part of the turner, although sometimes there is no choice. The point is not an important one, because the time required for setting the one or the other varies but slightly. In some instances the travelling stay is undoubtedly the more efficient, but a large number of turners are unable, through lack of skill, to make the best use of this. At the same time, even the best travelling stay is not a convenient accessory when fine work is required. In cases of this kind it is advisable to estimate for the more efficient method, and leave the turner to suffer if he is unable to use this.

Allowances are required for setting each cut and each tool, and also for the withdrawal of the carriage from the previous cut. This amount will depend upon the length of travel and the size of

the lathe. Under screw-cutting, where start cuts are relatively of more importance, will be found a reference to this.

Parting-off is dealt with under that head in Chapter XXIX. The work is not done quite so quickly as in capstans or parting-off machines, neither the cutting nor the handling, and as an independent operation it is advisable that another type of machine should be used. With some operations, parting-off in the lathe is unavoidable, and in such cases feeds of from 80 to 150 per inch can be used according to the strength of the tool used and the size of bar being cut. A fairly fast speed is advisable generally and, where a narrow tool is used, a fast speed and a fine feed are often found to be particularly beneficial.

An estimate for turning is taken out as follows. Let it be assumed that a mild steel shaft is to be turned, and that an estimate is required for the turning of same. The shaft dimensions are as shewn on page 306. The details of the operation would be as follows, the preparation of the lathe and the centering being treated as independent operations.

Fix carrier and place shaft between centres.
Fix tool ready for cutting.
Set cut and start lathe in motion.
Rough turn 2 inch diameter.
Return carriage to starting point.
Change carrier and shaft end for end.
Rough turn 1.75 inch diameter.
Change and fix tool for facing end.
Face first end.
Change carrier and shaft end for end.
Face second end.
Change and fix tool for finish turning.
Finish turn 2 inch diameter.
Change carrier and job end for end.
Finish turn 1.75 inch diameter.
Change and fix tool for facing shoulder.
Face shoulder.
Remove sharp edges and adjust diameter as required.

It is appreciated that for shafts of this type and size the more efficient method would be to rough turn and grind; also that facing could be done in the cheaper centering machine, but the object of the illustration is not to indicate how a shaft should be turned, so much as how to take out an estimate for turning. With a number of shafts to be done the operations would be run through one at a time, an extra carrier would be used and fixed while the cut was being taken up, and the tools would not be changed excepting for grinding or until all pieces had been done.

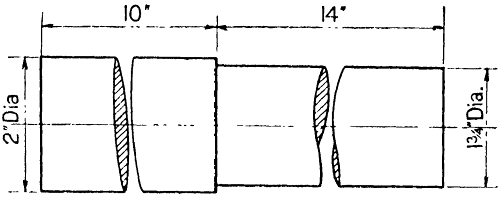
In estimates for turning of all kinds this method should be followed. If there are many different diameters to be turned the number of items will be increased; if these be so difficult to describe that figures become confusing, the sketch can be conveniently

lettered A, B, C, etc., so that there will be no difficulty in reference or checking. As a matter of interest an example of an estimate for a large intermediate marine shaft is shewn on p. 308.

Internal Work. In internal work the methods followed are largely the same as with that of an external character. The tools used are not so rigid as with external work because of the greater overhang, and also of the side thrust, due to the manner in which cutting must be done. In the majority of cases both the speed used and the depths of cut taken have to be reduced. This feature of internal work is specially referred to under screw-cutting, where, because of the fixed amount of material to be removed, a stated number of cuts is desirable. Drilling in the lathe is often a preparatory operation to boring.

SHAFT, PINION.

Part Mo. 2/132.
Material M.S. bar.



Order 36.
No. off 1.

Rough turn 1.75" dia.	$\frac{14 \times 1 \times 24}{96} = 3.50.$	
Rough turn 2" dia.	$\frac{10.5 \times 1 \times 24}{96} = 2.62.$	
Finish turn 2" dia.	$\frac{10.5 \times 1 \times 32}{57} = 5.9.$	
Finish turn 1.75" dia.	$\frac{14 \times 1 \times 32}{57} = 7.86.$	
Face shoulder	$\frac{.125 \times 3 \times 100}{57} = .66.$	
Face ends	$\frac{1 \times 3 \times 64 \times 2}{57} = 6.73.$	
		27.27
Add for contingencies 20 %	-	5.45
,, gauging and adjusting size	-	6.00
,, setting 6 times	-	6.00
,, start cuts 4	-	1.00
,, tools used 3	-	3.00
Estimated time	=	48.72 minutes.

Drilling in Lathe. Although the lathe is not adapted for efficient drilling, a certain amount of drilling in the lathe is unavoidable, and, in some instances, the saving of an operation with its attendant setting more than counterbalances the low rate at which the work is done. At the same time, drilling in the lathe from the solid is an operation to be avoided wherever possible.

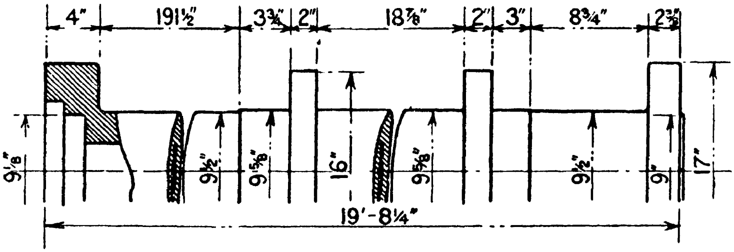
Drilling in the lathe is done by the use of both flat and twist drills, from the solid and from cored holes. In some instances a drill holder is mounted in the tool-rest making it possible for mechanical feed to be used, but the results are not, as a rule, good, and the practice is not so common as was the case a generation ago. Usually when twist drills are used these are carried in the tail-stock, this being fitted with a special drill socket, or, as is more commonly the case, the tail-stock is bored to the required Morse taper and the drills or the standard drill sockets carried direct.

The practice is thought by some people to be bad for the lathes. It certainly does not improve them; but production is the aim, and in the big majority of cases any injury which may be done passes unnoticed. A useful protection is to insert a thin sheet brass or copper sleeve between the drill shank and the tail-stock taper, so that in the event of a drill "going round" no harm will be done.

The feeds and speeds which can be used are variable items. The feed is generally limited by the strength of the turner, combined with the pitch of the tail-stock screw and the convenience for using extra leverage, and also the efficiency of the lathe thrust rather than with the drill, and in so far as the drill in use is large enough to tax either of these, the feed will become finer. In some works 300 feeds per inch are used in estimating for all sizes of drills. This is a fairly safe figure to use but, with drills well ground and soft material, particularly with the smaller sizes of drills, this can be improved upon, 250 feeds and less being attainable. The use of this fine feed is counteracted, perhaps, by the necessity for more "clearing" with the smaller drills, but this is an unsatisfactory method of covering the requirements, and with short holes, excepting the quantities be small or the high time allowed be lost, as it were, among other details, estimates so based are likely to be high. The question involves that of speed.

The speed at which drilling can be done is affected by the method of lubrication, more perhaps with the lathe than with any other type of machine. The horizontal position in which drilling must be done in the lathe makes it impossible for water to reach the drill point, excepting under force, and it is commoner to find that the method of lubrication is by the use of the old-fashioned ineffective drip-can. This means that when the hole drilled is deeper, say, than the diameter of the drill, the drill is cutting without lubrication, and this is one of the reasons why lathe drilling is usually so slow.

F.S. INNER INTERMEDIATE SHAFT



Part No. 1/41 Material; Forged M.S., roughly machined
Order 371. No. off 1.

Finish turn and face complete, and bore recesses.

		minutes.
Turn for stay	$\frac{6 \times 5 \times 16}{7} =$	69
Rough turn couplings	$\frac{4.5 \times 1 \times 8 \times 2}{7} =$	10
,, face couplings	$\frac{4 \times 2 \times 12 \times 4}{7} =$	55
,, turn collars	$\frac{3 \times 2 \times 8 \times 2}{7} =$	14
,, turn shaft	$\frac{221 \times 2 \times 8}{14} =$	253
,, out 6 corners		60
Return for stay	$\frac{6 \times 2 \times 16}{7} =$	27
Dry scrape shaft	$\frac{221 \times 2 \times 4}{10} =$	177
Wet scrape shaft	$\frac{221 \times 2 \times 4}{7} =$	253
Finish turn collars	$\frac{2.5 \times 2 \times 4 \times 2}{5} =$	8
,, face collars	$\frac{3 \times 2 \times 12 \times 4}{5} =$	57
Finish turn couplings	$\frac{4.5 \times 2 \times 4}{5} =$	7
Finish turn couplings	$\frac{3.5 \times 2 \times 4}{5} =$	6
Finish face couplings	$\frac{4.5 \times 2 \times 12 \times 4}{5} =$	86
Turn spigot	$\frac{.5 \times 4 \times 16}{10} =$	3
Carry forward - - - -		1085

		minutes.
Brought forward - - -		1085
Face spigot	$\frac{3 \times 3 \times 12}{14} =$	8
Finish 7 corners	$\frac{.5 \times 3 \times 7 \times 32}{10} =$	34
Finish 2 radii inside couplings		40
Turn 6 small radii		45
Bore recesses	$\frac{6 \times 6 \times 24}{10} =$	86
Face at back	$\frac{1 \times 4 \times 24 \times 2}{10} =$	19
		1317
Add 16.6 % for contingencies		219
Polish approx. 8000 sq. inches	$\frac{8000}{30} =$	267
Fit and draw centres - - -		180
Setting job and stays - - -		180
Start cuts - - - - - -		120
Tools and gauging - - - -		360
	Total	2643

Estimated time = 44 hours.

The deeper the hole, the more difficult it is to get rid of the heat generated and, with deep holes, it is not uncommon to find that water has to be applied to the outer surface of the material in order to cool it, and then, because of the great heat, the water often boils as it is applied. The syringe is used at times, but the results are not satisfactory, although it is an improvement on the brush or the drip-can.

In addition to the greater difficulty of keeping the material as well as the drill cool, and to the more frequent withdrawal of the drill for that purpose, the question of clearing, from the standpoint of the time involved, becomes increasingly important ; as the hole is made deeper the clearing necessary takes correspondingly longer because of the greater distance the drill has to be withdrawn and returned. When the pitch of the tail-stock screw is 4 threads per inch, and a hole is 8 inches deep, the screw must be revolved at least 64 times in the clearing or cooling and the return of the drill. The time spent in drilling a .75 inch hole 10 inches deep would be somewhat as follows. It is presumed that the drill will have to be withdrawn every .75 of an inch after the first.

This allows no time for cooling the material, but 22.4 per cent. of the total time is spent in handling, whereas with short holes handling of this kind is unnecessary. To avoid the complication of making a calculation of this kind it is advisable, where much

drilling is done in the lathe, to build up a table which would give complete times, with or without contingency allowances, so that these could be read at sight ; better still to provide forced lubrication.

When the old-fashioned but most useful handwheel is fitted to the tail-stock instead of the handle of recent years, which has nothing useful to recommend it, the time required for the withdrawal and return of drills in this way, because of the momentum of the handwheel, will be appreciably reduced.

Depth.	Cutting Time.	Time to Withdraw Drill.	Time to Cool Drill.
	Minutes.	Minutes.	Minutes.
·75	1.22	—	—
1.50	,,	—	—
2.25	,,	.12	.1
3·00	,,	.16	.1
3·75	,,	.20	.1
4·5	,,	.24	.1
5·25	,,	.28	.1
6	,,	·32	.1
6.75	,,	·36	.1
7·5	,,	.40	.1
8.25	,,	·44	.1
9	,,	.48	.1
9·75	,,	·52	.1
10.00	.41	—	—
Totals,	16.27	3·52	1.1

Drilling time - - - -	16.27 minutes
Withdrawing and return -	3·52 ,,
Cooling - - - - -	1.1 ,,
Total - - - - -	20.89 ,,

After drilling, holes are usually required to be bored with the single point tool in order to true up the drilled hole, which rarely runs true, and also to bring same to size, although with small holes reamers are commonly used for sizing purposes. Because of the varying influence of diameter and depth of hole, it is difficult to give reliable figures for depths of cut and for feeds for the various materials, but a table of the following kind will be found of much use as a guide, especially where the depth of hole is not greater than the diameter, or where the lathe is strong enough for a hole of the size concerned. A similar table to suit the requirements of each works should be looked upon as essential, and, if in this

table can be embodied the results of tests, efficiently carried out, its influence will be of much value.

BORING DATA—LATHE. (No. 15)

	Feet per Minute.		Dia. in Inches.	Depth of Cut.	Feeds per Inch.	Dia. in Inches.	Depth of Cut.	Feeds per Inch.
	Rough.	Finish.						
Mild Steel A.	60	40	1	.03	64	4	.13	32
Mild Steel B.	30	20	1½	.04	48	5	.16	32
Steel Casting	25	20	2	.06	40	6	.19	32
Cast Iron	30	20	2½	.08	32	7	.22	32
Tool Steel	20	12½	3	.10	32	8	.25	32
Gun Metal	60	40						
Soft Brass	90	60						

Allow 3 finishing cuts, 3″ dia. and below
Allow 2 finishing cuts, above 3″ dia.
For each time depth exceeds dia. allow 1 extra cut each for roughing and finishing.

To avoid continued calculation, a table can be built up to give the total time for drilling and boring, but setting should be left out. Alternatively, a table could be arranged so that drilling and boring are given separately, in which case the table could be of use whether the drilling was included in the operation or not.

This table, if to cover drilling and boring combined, would be as shewn in the form below.

HOLE-BORING TABLE—LATHE. (No 16)

INCLUDES DRILLING FROM SOLID AND BORING TO GAUGE.
THROUGH HOLES.

Material—Mild Steel, Grade A.

Dia.	Depth of Holes in Inches.									
	½	¾	1	1½	2	2½	3	4	5	6
½										
¾										
1										
1½										

All holes up to and including 1½″ dia. allowed for as being reamed.

If it were desired to give the time for drilling and boring separately, the following form of table would suit; if gauging and handling allowances were also kept separate, the use of a table so arranged could be extended, by the addition or subtraction of stated percentages, to cover all the materials in common use.

DRILLING AND BORING TABLE—LATHE. (No. 17)

Material—Mild Steel, Grade A.

Dia.	Operation.			Depth of Hole in Inches.								
		½	¾	1	1½	2	2½	3	3½	4	5	6
½	Drill											
	Bore											
¾	Drill											
	Bore											
1	Drill											
	Bore											

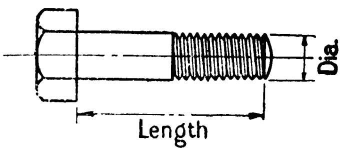
All holes up to and including 1½″ dia. allowed for as being reamed.

Tabulation of estimates for complete jobs, with lathe work, has not been carried very far. In some cases, particularly with external work, this is due to the variation in the work to be done. For tabulation to be possible there must be some absolute repetition, and where much of the external work is concerned, there is, comparatively speaking, little of this. The time for plain bolts, when done in the lathe, as small quantities are sometimes required to be done, can be conveniently tabulated, as also can plain bushes, whether steel or gun-metal.

Examples of tables for plain bolts and for plain gun-metal bushes are given below.

PLAIN BOLTS—LATHE. (No. 18)

Turn and Screw.

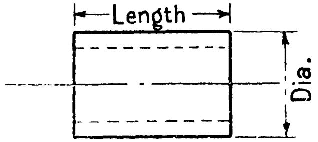


Material M.S. bar.

Diameter.		Length.											
Bolt.	Material.	1	2	3	4	5	6	7	8	9	10	11	12
½	1⅛	18	20	22	24	26	28	—	—	—	—	—	—
⅝	1⅜	21	23	25	28	30	32	34	37	—	—	—	—
¾	1½	—	26	29	31	33	35	37	40	42	—	—	—
⅞	1¾	—	29	31	33	36	38	40	42	45	47	—	—
1	2	—	32	34	36	38	40	43	45	47	49	51	54
1⅛	2¼	—	—	40	43	46	49	52	55	57	60	63	66
1¼	2⅜	—	—	43	46	48	51	54	56	59	62	64	67
1½	2⅞	—	—	—	57	60	64	67	70	73	76	80	83
1¾	3¼	—	—	—	66	69	73	77	80	84	87	91	94
2	3½	—	—	—	—	77	81	85	88	92	96	100	104

BUSHES—LATHE. (No. 19)

Bore, Face, and Turn.



Material G.M.

Diameter	1	1¼	1½	1¾	2	2½	3	3½	4	5	6
1st inch in length	12.0	12.7	13.3	14.0	14.7	16	17.3	18.7	20.0	23	25
Plus per inch	4.0	4.3	4.7	5.0	5.3	6.0	6.7	7.3	8.0	8.7	9.3
Fitting into position	1	1¼	1½	1¾	2	2½	3	3½	4	5	6
Diameter	7	8	9	10	11	12	13	14	15	16	
1st inch in length	27	29	31	33	35	37	39	41	43	45	
Plus per inch	10.0	10.7	11.3	12.0	12.7	13.3	14.0	14.7	15.3	16.0	
Fitting into position	7	8	9	10	11	12	13	14	15	16	

Other items which can be similarly treated are flanges, glands, rings, couplings, pulleys, nuts, pistons and plain shafting. A most useful table is one giving the times required for turning different radii on varying diameters.

Screw-cutting. In the term screw-cutting is covered the cutting of threads of all types, vee, square, acme and worm threads. The formula used for estimating the rate of output possible is the same in each case, although there are differences in the methods of cutting.

One factor which needs to be observed is the influence of the pitch of the thread on the length of travel. To estimators who are not turners this is often overlooked or not sufficiently understood, and sometimes considerable errors in estimates are to be found. The difficulty is usually referred to as that of the "odd thread," and is caused by the fact that, in cutting threads on the lathe, one leading screw is used to cut threads of all pitches, gear-wheels being used to obtain the different pitches. Thus, where the pitch of the leading screw is 2 threads per inch, and a thread be cut whose pitch is 7 threads per inch, the "screw-cutting" tool, for cuts taken after the first, will be brought into its correct position, that is, will follow the path made by the first cut, only when the "nut" is "dropped" at any even inch while, if the pitch of the thread being cut contained a fraction, as, say, 1¾ threads per inch, the correct position of the tool could be secured once in every 3½ inches, that is, in a number of threads of the leading screw divisible by 1¾.

In such cases, the length of travel necessary to enable the tool to cut a thread and "drop in" is equal to the length of thread plus the difference between such length and the shortest additional distance divisible by the appropriate factor. If a thread 1 inch long were required, whose pitch was 1¾ threads per inch, the minimum

amount of travel in which the thread could be cut, using a leading screw of .5 inch pitch, would be $3\frac{1}{2}$ inches; in other words, as much travel would be required to cut a thread of that pitch, 1 inch long, as it would another of the same pitch 3 inches long, and the same amount of time would be taken although, obviously, the tool wear would be less. With leading screws of other pitches the same principle, of course, applies.

The common practice to-day, more particularly with American lathes, is to provide a reverse belt, so that for "odd" pitches the lathe movement can be reversed, making it unnecessary to release the nut until the thread has been completed. This is most economical in the cutting of short threads, and is more convenient in the case of internal threads than with those cut externally. In the interests of economy it is desirable to make sure, however, that the reverse speed is faster, and sufficiently faster, than the forward speed, to ensure economy of time. It is ridiculous of course to find instances where this is not so, but they are to be found.

The decision to allow in an estimate for the return of the tool by reversal of the movement, or by the withdrawal of the nut, will depend upon the time required for each method, the shortest, consistent with safety, being chosen.

Where threads of widely varying lengths have to be cut, it is useful to build up a table showing the time required for the return, by hand, to the starting place, of the saddles for the different size lathes, or even of individual lathes when the course is justified, because the return of the saddle takes up an appreciable portion of the time required to cut a thread of any kind. The values in such a table should be expressed in decimals of a minute per foot of thread cut, of each pitch and type, and this would present a ready means of comparison with the time which would be required if a reverse belt were used.

Vee Threads. The cutting of vee threads, generally speaking, is the easiest of all screw-cutting. This is due principally to the possibility of using the chaser, which enables inaccuracies of form of thread to be readily corrected. The quality of the work which can be accepted varies to a considerable degree, and it is difficult to lay down any hard-and-fast rules as to the number of cuts required to complete any given thread. In some instances, accurately formed threads are not sought; provided the nut can be made to grip, nothing further is required. On the other hand, the form of thread may be so important a matter that accuracy of the diameters at the top, the root and the pitch line is necessary, a fine finish being called for at the same time.

In ascertaining the number of cuts which are necessary to give the class of finish required there are three main factors which need to be considered:

1. The amount of material to be removed.
2. The strength of tool point.
3. The class of finish.

Dealing with the question of the removal of material, and leaving out of the question, for the moment, its class, the two chief factors are depth of thread and strength of tool.

The Whitworth thread is cut to an angle of 55 degrees, and if it were carried to a sharp point would be equal to .96 of the pitch ; one sixth of the depth, however, is rounded off at the top and bottom of the thread, and this reduces the depth from .96 to .64 of the pitch. In this rounding off, the actual amount becomes greater as the pitch is increased, and of course this fact makes the radius at the top and the bottom of the thread larger. With the cutting of the finer pitches the difficulty is to keep the " point " of the tool in good condition, and when it is remembered that the radii of threads with pitches of 3 and 20 threads to the inch are .0457 and .0068 inches respectively, this difficulty and its disappearance as the pitches get coarser will be appreciated. A larger radius means a stronger tool, and a stronger tool means the capacity to take heavier cuts.

In practice, however, the theory appears to be held that, relatively speaking, the tool for cutting, say, 3 threads to the inch is no stronger than that required when 20 threads are being cut, and the depth of cuts presumed to be necessary are taken as being of equal value. Two items of the formula for estimating the time required to cut threads are number of cuts and feeds per inch ; feeds per inch in this case will be threads per inch. In the ordinary way, these two items are multiplied each time the formula is used. In a praiseworthy attempt, however, to eliminate calculation and to fix the number of cuts required for the different pitches at the same time, the items mentioned are sometimes used to build up a factor, as with, say, 10 threads per inch and 14 cuts per thread ; the product of these two is 140, and this factor is used to obtain the number of cuts for all pitches. Then

$$\text{the number of cuts required} = \frac{\text{factor}}{\text{threads per inch}}$$

and for 20 threads to the inch 7 cuts would be allowed, while for 3 threads per inch 47 cuts would be shewn as necessary. In some works the number of cuts allowed in this way, for threads cut in mild steel, for the three pitches quoted are 12, 24 and 80, the factor used being 240.

It will be obvious that while 12 cuts for a thread whose pitch is 20 to the inch may not be so far out, those quoted for 10 and 3 threads are much too high, and that, while simplicity in dealing with the question has been achieved, it has been at the expense of accuracy.

Really it is impossible for one calculation factor to be used to deal accurately with the removal of material, when such removal is affected by varying considerations. As has been stated, the removal of material, with threads of the finer pitches, is controlled by the strength of the tool point to a much greater extent than is

the case with threads of coarser pitches, and to allow the same depth of cut when cutting 3 threads per inch as when cutting 20 threads is not logical. True, with the thread of coarser pitch a much larger amount of material has to be removed, but the removal of this material can be distributed over a longer cutting edge than is the case with the finer pitched thread, and this relieves the weakest part of the tool, the tool point.

In using a factor so inaccurately arrived at, it is probable that, seeing most of the threads cut are short in length and that screw-cutting is generally linked up with general turning, these are the reasons for the weakness not having been disclosed. With screw-cutting being continuously done, or with long threads, very grave overestimation would take place. To take an example. A lad working for 5 hours, cut and fitted to gauge, mild steel being the material used, 96 threads, .75 inches diameter, 1.25 inches long—3.12 minutes per thread. On a basis of a cutting speed of 20 feet per minute, a length of travel of 1.5 inches, 24 cuts, 5 seconds per start cut and 30 seconds for changing from piece to piece twice (15 seconds each time), and no allowances for contingencies, the time per thread would work out at 6 minutes, 23 seconds each, or 10 hours, 12 minutes the lot. In another works, 12 minutes each is the time estimated for the same amount of work, 18 minutes being the job rate.

If a general approximate accuracy is to be aimed at, accuracy in detail becomes a first consideration, and this will be best assured by a recognition of fundamentals. In the case in point, it will be found that, as the work involved varies, the factor for estimating must be varied likewise. In considering the question, it is desirable to examine the possibilities of taking the factors used a stage farther for the purpose of an additional saving in calculation.

For estimating to be done at all, the cutting speeds at which the different classes of material can be cut must be known, and so long as these remain constant, it is an advantage for them to be embodied in factors which cover cuts, feeds, and speeds. In such factors, cuts and speeds would be taken in accordance with the depth and pitch of the thread concerned, but all threads would be presumed to be cut on a diameter of 1 inch. The various factors would be arrived at as follows :

$$\text{factor} = \frac{1 \text{ inch} \times \text{number of cuts} \times \text{threads per inch}}{\text{revolutions at appropriate cutting speed}}.$$

The revolutions required would be those which would give material, 1 inch diameter of a specified class, the cutting speed decided upon as

mild steel - - - 20 feet per minute.
brass - - - 40 ,, ,,

Then for mild steel 76 revolutions per minute would be required, and all factors for mild steel would be based on this speed. The

figures quoted below illustrate how the various factors can be arrived at.

$$A = \text{number of cuts} \times \text{threads per inch.}$$

$$B = \frac{\text{number of cuts} \times \text{threads per inch}}{76}.$$

SCREW-CUTTING FACTORS—LATHE. (No. 20)

MILD STEEL.

THREADS.		Number of Cuts.	A.	B.	Zone Factor.
Pei Inch.	Depth.				
20	.032	11	220	2.9	—
18	.035	11	198	2.6	—
16	.040	11	176	2.3	—
14	.045	12	168	2.2	—
12	.053	13	156	2.0	
11	.058	14	154	2.0	2.0
10	.064	15	150	2.0	
9	.068	16	144	1.9	
8	.080	17	136	1.8	
7	.091	18	126	1.7	1.75
6	.106	19	114	1.5	
5	.128	21	105	1.4	1.5
$4\frac{1}{2}$	.142	23	104	1.4	
4	.160	25	100	1.3	
$3\frac{1}{2}$	.183	27	95	1.3	1.33
$3\frac{1}{4}$	.197	29	95	1.3	
3	.213	31	93	1.3	

The time for cutting threads in mild steel would be arrived at as follows:

$$\text{cutting time} = \text{length of travel} \times \text{diameter} \times \text{factor.}$$

Then if the cutting time were required for cutting a thread 3 inches diameter, 6 inches long, with a pitch of 6 threads to the inch, the procedure would be as follows, 7 inches travel of the tool being allowed for:

$$\text{cutting time} = 7 \times 3 \times 1.5 = 31.5 \text{ minutes.}$$

If, in order to reduce the numbers of factors, it were decided to use what have been described as zone factors, the procedure would be the same, but the use of the zone factor, in some cases, would have the effect of increasing or decreasing the time allowed in a small degree.

Factors for the cutting of threads in different materials can be conveniently tabulated in the following form to suit the requirements of individual works :

SCREW-CUTTING FACTORS—LATHE. (No. 21)

VARIOUS MATERIALS.

Threads.		Factors.						
Per Inch.	Depth.	Mild Steel.		Steel Castings.	Cast Iron.	Tool Steel.	Gun-metal.	Soft Brass.
		A.	B.					
20	.032							
18	.035							
3	.213							

To analyze the results of the use of these factors will be to discover what appears to be an error, which has probably had some influence in bringing about the use of one factor for all threads. This apparent error is that less time would be allowed for the cutting of threads of coarse pitch than of fine ; that, for example, less time is required in the cutting of a screw of 18 threads per inch on a 4 inch diameter than would be the case if 3 threads were cut on the same diameter. The formula is as follows :

$$\text{cutting time} = \text{length of travel} \times \text{diameter} \times \text{factor},$$

and the cutting time, in the case of the fine and coarse threads, using the factors quoted, if 3 inches travel of the saddle were required would be 31.2 minutes and 15.6 minutes respectively. The difference is considerable.

In the first place, however, it should be noted that the feed is 6 times as fast for the thread of coarse pitch, and consequently each cut takes but one sixth of the time required for a cut on the finer pitched thread ; on the other hand, the depth of the coarse thread is 6 times as great as that of the fine thread, the one appearing to counterbalance the other ; if the depth of each individual cut taken were the same in each case, the total cutting times would be identical, but—and this is the second point—the depth of cut should not be the same, and the difference possible will be reflected in the proportionally smaller number of cuts required for the coarser thread. Thus, paradoxical as it may appear at first, coarse threads can be cut in less time than can fine threads, and though the allowance for the withdrawal of tool and the starting of cuts will tend

to equalize the two, it is not sufficient, excepting where, as is often the case, the time allowed per start cut is abnormally high.

The matter can be illustrated if a few estimates be worked out, 10 seconds being allowed for the withdrawal of the tool, the return of the saddle, and the starting of the next cut.

A. Vee thread, 18 to the inch, 4″ diameter, length of tool travel 3″.

$$\text{Cutting time} = \frac{3 \times 11 \times 18}{19} = 31.2$$
$$\text{Start cuts} = 11 \times 10 \text{ seconds} = 1.8$$
$$\overline{33.0}$$

B. Vee thread, 3 to the inch, 4″ diameter, length of tool travel 3″, cuts the same depth as in *A*.

$$\text{Cutting time} = \frac{3 \times 66 \times 3}{19} = 31.2$$
$$\text{Start cuts} = 66 \times 10 \text{ seconds} = 11$$
$$\overline{42.2}$$

C. Vee thread, 3 to the inch, 4″ diameter, length of tool travel 3″, cuts averaging .0069 inches deep.

$$\text{Cutting time} = \frac{3 \times 31 \times 3}{19} = 14.7$$
$$\text{Start cuts} = 31 \times 10 \text{ seconds} = 5.1$$
$$\overline{19.8}$$

To the time estimated above, gauging and contingency allowances remain to be added, but these do not affect the issue.

The question is one of real interest and deserves further attention, there being room for research work as to the relative influences of speed, depth of cut and point of tool. One feature deserving special attention is the extent by which the increasing depths of cut, which can be taken as the thread pitches get coarser, can be counterbalanced by increased cutting speed as the pitches become finer.

Where much screw-cutting is done, tables can be profitably built up to give the actual figures without calculation, although, owing to screw-cutting so commonly forming a portion of a turning operation which must be estimated, it is desirable, in order to avoid mistakes, that in such a table cutting times only should be given independently of gauging and contingency allowances. In any case, time for setting can hardly be included, owing to the conditions not being known.

When a definite class of work is to be handled, the operation being screw-cutting only, and its amount justifies the trouble, a

table on the lines of the form below may be found useful, everything being included except time for setting.

VEE THREADS.

ESTIMATED TIMES FOR CUTTING THREADS—M.S. SHAFTS.

(No. 22).

TABLE INCLUDES ALL ITEMS EXCEPT SETTING.

Diameter.	Threads per Inch.	Length of Thread.											
		1	2	3	4	5	6	7	8	9	10	11	12
$\frac{1}{4}$	20												
$\frac{5}{16}$	18												
$\frac{3}{8}$	16												
$\frac{1}{2}$	12												
4	3												

A variation of the above arrangement is possible by giving times for the first inch of thread in different materials, together with additional figures for each inch of thread cut. Such a table could be arranged to cover the different classes of material used.

When the tabulation done is for cutting time only, it is a weakness to leave the gauging and handling time to be estimated for each job without the provision of a guide of some kind. These times can be estimated by the use of a suitable formula and they can also be tabulated if desired.

The time required for withdrawing the saddle, when the thread cut is 5 feet long, will obviously be greater than when the thread being cut is 1 inch long only. In similar manner, chasing and gauging will be affected.

Taking the return of the saddle first, where the lathes used vary in size, the time required would vary also, and different allowances would become necessary, provision for which can be made as required. These can all be conveniently provided for by the use of minimum start cut allowances, the term "start cut" to include time for returning the saddle, increasing these as the length of screw exceeds those on which the allowances were based.

In arranging these allowances, it will be convenient to allow time for the withdrawal of the tool and the setting of cuts independently of the return of the saddle. The former is not affected by the length of thread as is the latter. Then, assuming that the setting of cuts takes 2 minutes and that, for a thread 5 feet long, the time required for the return of the saddle is six minutes, or .1 of a minute per inch,

the combined time for start cuts for any length of thread could be obtained by the use of the following formula :

Start cut time = time for setting + (time per inch × length in inches).

For a thread of the same pitch referred to above, 48 inches long, the calculation would be as follows :

$$\text{Start cut time} = 2 + (.1 \times 48) = 6.8 \text{ minutes.}$$

When the class of finish required varies and the tabulated time is known not to be sufficient to cover the higher grade finishes required, and chasing is necessary, this can be provided for by the use of a similar formula. Let it be assumed that $1\frac{1}{2}$ minutes are necessary for the chasing of a short thread, 1 inch diameter, 1 inch long, and that for a similar size of thread, 30 inches long, 15 minutes are necessary. Then it would appear that, if 1 minute were allowed as a minimum plus .5 of a minute per inch, the time for varying lengths could be arrived at. Further, as diameter is an equally effective factor, it becomes convenient for all the factors to be dealt with in the one formula. Such a formula could be as follows:

$$\text{Chasing time in minutes} = 1 + (.5 \times \text{length} \times \text{diameter}).$$

Of course, because of the nature of the chasing operation, the time for gauging would be included in this formula.

Some allowance of this kind will be necessary for the gauging of long threads where the class of work to be done does not call for chasing because, obviously, some gauging is necessary, and the gauging of a long thread will take more time than a short one. This can be provided for by the use of a similar factor.

$$\text{Gauging time} = .5 + (.2 \times \text{length} \times \text{diameter}).$$

Square Threads are affected by most of the considerations which affect vee threads, and these can be provided for in a similar manner. There does not appear to be any generally accepted standard for the depth of square threads, although nominally, a square thread is square, not only in shape but in dimension also ; that is, if a thread is .25 of an inch wide, it is .25 of an inch deep. This variation, however, need cause no difficulty with regard to the provision of factors.

The chief consideration, apart from the question of the material being cut, is, again, class of finish. In some works it is a rule that one tool down must be sufficient, in others two tools are recognized as being necessary, one for roughing and one for finishing. Of course, any factor fixed must be based upon one or other of these practices.

The speed at which square threads can be cut is similar to that used for vee threads, although in some cases the tendency is to use somewhat higher speeds, 20 to 30 feet per minute for mild steel being possible ; the speed for brass is controlled by the nature of

the job as to whether the tool runs into a clearance or has to be withdrawn at a given point, rather than by the cutting capacity of the tool.

The depth of cut possible varies as with vee threads, but hardly to the same extent. It is common to find the cutting of square threads of the finer pitches done with cuts as fine as .002 of an inch deep. This may be necessary when the pitch is .125 of an inch only, the tool width being approximately .0625 of an inch, but for pitches .25 of an inch and upwards the depth of cut taken can be increased from .004 to .01 of an inch.

This will depend to some extent on the width of tool used. There is a considerable amount of misconception over this matter, and there are very few handbooks, if any, which give any assistance to the practical turner on this question. It is generally stated that the width of tool must be one half the dimensions of the pitch of the thread. That this is not the case will readily be seen if the manner in which a square thread is measured is examined.

The pitch of a thread is measured parallel with its axis, but the thread itself is cut at an angle with the axis, and it follows that the tool, to cut efficiently, should be set square with the thread being cut, not with the axis of the screw. This means that the tool, when cutting, must be set at the appropriate angle, and it will be appreciated that the question of width of tool will be affected. To take an extreme case to emphasize the point: a square thread .5 of an inch pitch, 6 inches lead, in other words, a thread with 12 starts, the diameter being assumed to be 2 inches, would require a tool not .25 of an inch wide, one half the pitch, but .1818 of an inch only.

From the diagram given below will be seen the reason for this. A square thread when measured square with its pitch angle

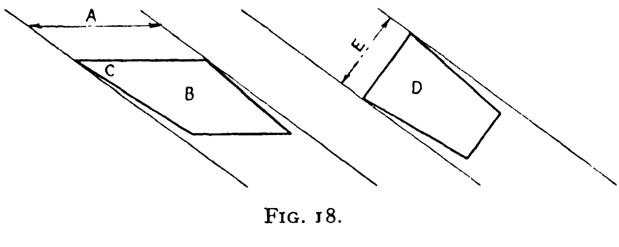


FIG. 18.

is never as wide as one half its pitch, and when a tool is made to that width it must be made weak on its leading side, see " C " in diagram, and be set in an unsuitable position for cutting. When set square with the pitch angle or, in the case of multiple threads, with the angle of the lead, as shown at " D," the tool is in a much better position for cutting, but it must of course be considerably narrower than one half the pitch. As a matter of fact, the widths of square thread tools vary for each pitch, lead, and diameter on

which they are used. When threads of fast leads are cut with the tool set as recommended, the sides of the thread will not be quite straight, because cutting will be done both above and below the centre. Where extreme accuracy is essential the sides of the thread can be finished separately.

The connection with the question of the estimating of rates of production will be seen from the following incident.

A job rate had been given for the cutting of square threads with four starts, the pitch being .5 of an inch, the lead 2 inches, and the diameter 1.5 inches. Much trouble was experienced in cutting the threads, and a complaint was made by the turner that the job rate was too small, " it was not possible even to look at the job in the time." The complaint was supported by the foreman, who stated that the steel being cut was bad, that the tools would not stand, and that, in his opinion, the job needed to be re-estimated.

As a result of investigation, it was found that the tool was made one half the width of the pitch and was set in the only position in which it could cut a thread which would not be too wide, but which was such that it could hardly cut at all and stand. The tool was corrected for width and shape, as was also the position in which it was held, and the job rate was proved to be satisfactory.

It will be found that for cutting square threads, the tool shape not being affected by the pitch in the same manner as with vee threads, the difference in the depths of cut which can be taken is not so great, and the time required for threads up to, say, .5 of an inch pitch becomes more a matter of depth than of pitch, and, provided the depth is standard, that is, one half of the pitch, the cutting time will be the same, because, although the depth of thread may be doubled, the feeds per inch are also doubled.

On a basis of 20 feet cutting speed, and cuts of .004 of an inch deep, plus 2 cuts to give a finish and remove spring, the factor would be 1.66 minutes per inch of travel per inch of diameter. If two tools down were used, the cuts in each case being .004 of an inch deep, the factor would need to be doubled.

Start cuts would be estimated as with vee threads. The depth would be best based on 1 inch as a unit, at which, with cuts .004 of an inch deep, 250 cuts would be required. These at 10 seconds each would give a total of 42 minutes for the setting of cuts. Then, if the figure of 42 minutes, covering the withdrawal of tool and resetting of same for the next cut, be multiplied by the actual depth of thread in inches, the resultant time will be that amount required for the start cuts of a thread of that depth. If, further, the time for the return of the saddle for a thread 5 feet long be taken as 84 minutes, this will be equal to 1.4 minutes per inch of saddle travel. The start cut allowance would then be obtainable by the use of the formula given below :

$$\text{Start-cut time} = (42 \times \text{depth}) + (1.4 \times \text{depth} \times \text{length}).$$

Gauging can be dealt with similarly. Where a reasonably good fit is required, the gauge may have to be tried several times before the thread is finished, and the longer and larger the diameter of the thread, the more difficulty is likely to be experienced in getting the thread to pass the gauge over its whole length, and the longer will the necessary adjustments take. This can be provided for as follows, although both the minimum and the supplementary allowances can be modified to suit the gauging requirements.

Allow 8 minutes minimum.

Allow .33 minutes per inch of length.

Allow .33 minutes per inch of diameter.

The total gauging time would be obtained thus :

$$\text{Gauging time} = 8 + (.33 \times \text{length} \times \text{diameter}).$$

With brass, gun-metal, and with very soft steels, the initial gauging allowance of 8 minutes can be reduced to 4 minutes because tool wear is very slight, and, with the tool width right and correct diameters obtained, gauging and fitting should be but a small task. Two minutes per tool used should be added for setting.

In the case of there being more than one start to a screw, more time will be taken if only because of the additional start cuts, but gauging also becomes more difficult, and in some cases cutting speed has to be reduced because of the fast saddle travel. It is found necessary with some particularly fast pitches to make special arrangements for driving the lathe. These of course would have to be dealt with specially.

It is possible to estimate a multiple start thread the same as one with a single start. It is a question of the feed and speed which can be used, but, where the additional starts do not interfere with the speed as with slow leads, the ordinary factor can be used. Theoretically, the cutting time should not be increased but, where the quantities are small, and multiple threads are not often cut, it is usually found that time is lost, and, as a matter of discretion rather than of proved necessity, an addition of, say, 10 per cent. to the cutting time for each start above one may be found advisable.

Acme threads and worms can be dealt with in a similar manner. With these the threads cannot be completed with one tool, and it is a common practice to rip, as though the thread were square, finishing the thread separately. Dealt with as indicated for square and vee threads, factors can be arranged for all the different types of threads and finishes required. These could be all embodied in one table if desired, provided suitable guidance instructions are given also as to the extent of their application. The table could also be arranged to give zone factors for specified ranges of sizes, but this is a matter which must be decided upon local considerations.

On a basis of cutting speed as shewn a table of the following kind can be usefully built up :

SQUARE THREAD FACTORS. (No. 23)

EXTERNAL WORK. 1 TOOL DOWN ALLOWED FOR.

Material.	Brass.	Gun-Metal.	Mild Steel.	Tool Steel.	Cast Iron.
Cutting speed in feet	40	30	20	12½	20
Depth of cut in inches	.005	.005	.004	.003	.005
Factor	.66	.85	1.66	3.5	1.33
Start cuts in minutes	34	34	42	55	34
Minimum gauging	4	4	6	8	5

$$\text{Cutting time} = \text{diameter} \times \text{length} \times \text{factor} \times \frac{\text{actual depth}}{\text{standard depth}}.$$

Contingency allowance $= x$ percentage of cutting time.

Gauging allowance = minimum + (.33 minutes × length × diameter × starts).

Start cuts in minutes = factor × depth of thread in inches × starts + (1.4 × depth × length × starts).

Tool setting allowance = 2 minutes per tool used.

For 2 tools down double all items except gauging.

For close fitting multiple threads add 10 per cent. per start to cutting times.

For standard depth divide pitch × 2.

For internal threads add as follows to all items :

When diameter exceeds depth 6 – 5 – 4 – 3 – 2 – 1 – times.
Add percentage to cutting time 25, 33, 40, 45, 50, 50.

When depth exceeds diameter twice, add 100 %.

When depth exceeds diameter once, add 75 %.

An example of an estimate so based is as follows. Assume a 2 start thread, .5 inch pitch, 1 inch lead, depth .25 inch, length 20 inches, diameter 2 inches, material mild steel, the finish requiring 2 tools down. Then

$$\text{Cutting time} = (2 \times 21 \times 1.66)\frac{.25}{.25} \times 2 = 140$$

Contingency allowance = 35

Gauging time = 6 × 2 + (.33 × 20 × 2 × 2) = 38.6

Start cuts = 42 × .25 × 2 + (1.4 × .25 × 20 × 2) = 35

Tool setting allowance = 4

252.6

Estimated time = 4 hours, 13 minutes.

For the cutting of internal threads it is less easy to state the number of cuts which will be required, because of the differences in diameters and depths of the holes, and also of the pitches. For example, to cut threads of a given pitch in holes 1 inch diameter, 1 inch deep, and 3 inches deep, and in holes 10 inches diameter, 1 inch deep, and 20 inches deep, represents four different problems, which cannot be catered for by any single cutting factor. Extra cuts will be required, accordingly as the depth of the hole at which the tool is cutting increases relative to the diameter, and as the cut which the tool is capable of taking is heavy enough to put undue stress on the tool rest. Thus, if a thread whose pitch is 12 to the inch were being cut to a depth of 1 inch, in a hole 10 inches in diameter, the weakest factor would be the tool point rather than the tool support, and the number of cuts required, so far as cutting possibilities were concerned, would be no more than for an external thread; the use of the chaser would be more difficult, as also would the gauging necessary.

It is not suggested that in the ordinary way it is practicable to obtain such close accuracy as would appear to be called for by the references made. It is easily possible to overdo matters of this kind; at the same time it is a mistaken policy to build up tables or fix upon the use of certain factors, which may be in the nature of a compromise, excepting the extent to which such compromise has been made is known. Where all the facts are known, then factors may be used and provisos be laid down, as to the exceptions, where their use will not be satisfactory.

Thus, in the cutting of internal threads, additional cuts will be required over those necessary for external work, as follows:

1. As the tool itself is weaker.
2. As the depth at which the tool has to cut exceeds the diameter of hole.

It is a common experience to find that the efficiency of internal boring and screw-cutting tools is not more than 66.6 per cent. of that obtained with external tools, while this is rapidly reduced as the depth of hole exceeds the diameter. To counteract this, it is of course desirable to do as much work as possible with tools which cut on each side, and, with internal screw-cutting, the use of taps for small threads should be pushed, either with or without preliminary aid from the single point screw-cutting tool.

Assuming there is no question of the strength of the lathe and tool-rest, a formula is necessary which will give the relative value of an internal cutting tool when that portion which is unsupported is so many times as long as its section. For example, a tool whose section is .75 inches is weaker when unsupported for a distance of 6 inches than is a tool whose section is 1 inch. Then, although each tool may be capable of taking a cut of the same depth, when supported within one inch of its cutting point, the one inch section tool would be able to withstand a heavier cut, when unsupported for a distance of 6 inches from its cutting point, than would the tool of .75 inch

section, although in each case the strength of the tool would be reduced. This is a matter upon which there is room for research, because, as a rule, production estimators are neither given the opportunity nor the time to prove these matters for themselves.

Internal work is likely to take 50 per cent. longer than similar external work, and this will be increased as the comparative rigidity of the tool used is reduced. No definite rules can be laid down, and much must be left to the discretion of the individual estimator. The figures given in the table on page 325 indicate the lines on which such allowances should be made.

There are many other classes of work done on lathes which have not been mentioned. This is unavoidable, because of their multiplicity, but the methods by which production can be estimated, in such cases, are similar and can be applied without difficulty.

CHAPTER XXIX

PRODUCTION ESTIMATING. CAPSTAN AND AUTOMATIC WORK

WHILE capstan and turret lathes are different from the automatic turning lathe, the difference is one of machine design and function rather than of process; both are "turning" machines, and they differ from the plain engine lathe chiefly in the manner in which the cutting tools used are held and operated, size reproduction being possible without the individual adjustment of tools per piece worked upon. In considering the estimating of rates of production, capstan and turret lathes can be treated as lathes adapted to carry more than one tool, each tool being provided with its own stop, and so arranged that the size to which each tool is set can be reproduced so long as the life of the tool allows. The automatic machine can be regarded as a capstan which, in addition to the equipment over the lathe embodied therein, is arranged to run, once set, without attention, feeding itself so long as the supply of material lasts, whether that supply be in bar or in individual pieces. Attention is necessary of course as with capstans to see that the tools are reground and reset as required.

The methods of estimating, therefore, will follow closely those used in connection with lathe work. The number of cuts required is less, the individual adjustment of the tools for each cut is obviated, less gauging is necessary and the cutting speed used is often much greater.

Each detail of the operation must be estimated separately in accordance with its nature; time must be allowed for changing from tool to tool, for feeding the bar forward or for setting separate pieces. The upkeep of tools, regrinding and resetting, must be allowed for on the basis of a percentage on cutting time. Where hand-fed machines are used, it is the practice, in some works, to treat individual observation as being the only method which can be applied to obtain an adequate idea of the rate of output. This of course is a mistake, if only for the reason that the record obtained is that of the result of one worker's efforts. For this purpose, the results of observations should be collated so that a standard could be fixed which would be generally applicable. Even then the speeds used and the feeds obtained should be noted for the purpose

of ensuring that the latter are satisfactory. Again, when motions only are concerned there is no justification for accepting the results of superficial observations at their face value.

The question of the efficient operation of hand-fed machines is a difficult one because of the different ideas which exist as to the possibilities. In some parts of the country four times the amount of work is done as in others, and the difficulty will be appreciated of asking for four times the output from a worker or even of getting a foreman to believe that such an increase is possible. As an example, a case might be cited where the actual cost of a complete article, the manufacture of which was composed principally of capstan operations, was 2 shillings and 6 pence. The cost as per job rates should not have exceeded $7\frac{1}{2}$ pence. One of the reasons given for the high cost was the "low job rates," these being claimed to represent impossible performances, discouraging the workers thereby. Under other supervision the cost was reduced to $5\frac{3}{4}$ pence, which was in keeping with that of other manufacturers.

Over against this, as an indication of the need for knowledge as well as method, the relation of an interesting incident is justified. An old foreman had been responsible for the fixing of piece-work job rates and had been successful in obtaining really economical production accompanied by fair earnings for the workers. In consequence of changes in management, the fixing of job rates was transferred to a rate-fixing department, and in the words of one of the rate-fixers he "was ashamed to put the times down on paper, they were so small." His lowest estimate for really light single operation jobs was 15 seconds, yet similar work in other districts was being done in 8 seconds as a matter of every-day practice, and had been done in that same works.

A difficulty is experienced sometimes as to the best means of supervising the fixing of job rates which, as the result of observation, are proposed for work to be done on hand-fed machines, the conditions at times being so difficult that there are no opportunities for discussion and reference. In one such case, on a light class of work, a general guiding instruction was given that, without reference, no observed or estimated time was to be used in the fixing of job rates for the use of any one tool, including the turning of the capstan head to bring the tool into position, if the time exceeded 3 seconds. This instruction helped considerably in pulling up the inefficiencies of tools, methods, machines and workers.

The speeds which can be used on capstan work are perhaps more variable than with lathe work. With lathe work, the tendency of high cutting speeds is to cause vibration, and this sometimes constitutes a limiting factor. With capstans, the roller and other tool steadies serve to reduce this tendency to a minimum, and where the tools will stand higher speeds these can generally be used. The cutting speeds at which steels known as mild steel can be cut vary by upwards of 100 per cent. So great is the difference and so important the influence on the cost of working that some firms

refuse to use those of English manufacture, which are often found to be harder to work than the American steels. In some works the cutting speeds used on capstan work are as low as 40 feet per minute, the feeds per inch being as fine as 150.

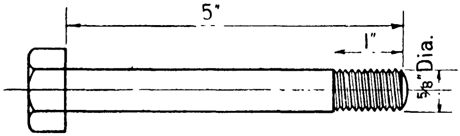
The speed at which screwing with dies can be done is of less importance than for turning, because of the comparatively small proportion of the whole the screwing time usually forms, but the advantage of a good free-working steel is reflected in the reduced amount of work spoilt in screwing. Screwing speeds vary from about 8 feet upwards according to the nature of the material and the pitch of the thread being cut; with fine threaded brass work, the speed is more a matter of ability to handle the dies than of their cutting capacity. The speeds used for mild steel are generally between 10 and 20 feet, but it is advisable where there is any doubt to use a slow rather than a fast speed.

When drilling and reaming are done on capstans, the method of estimating is similar to that followed for the same processes on the drilling machine, and the same remarks apply generally to automatic machine work.

Below is given a sample estimate for the turning of a plain bolt, the form being suitable for capstan, turret or automatic machine work.

BOLT CYLINDER.

P.S. 24 F.
M.S. bar.



Order No. 336.
No. off 100.
MachineNo. C29

Turn, screw and part off.

Turn shank	$\frac{5.1 \times 96}{175}$	$= 2.79$
Face head	$\frac{.35 \times 100}{175}$	$= .20$
Radius end		$= .18$
Screw	$\frac{1 \times 11}{61}$	$= .18$
Part-off	$\frac{.66 \times 120}{175}$	$= .457$
		3.807
Contingencies 25 %		$= .952$
Feed bar forward		$= .12$
Change tool to tool		$= .6$
Gauge as required		$= .18$
Total time		$= 5.659$

The time for setting needs to be dealt with similarly, only these require collated observations of work satisfactorily done. These having been taken, a table can be built up shewing the time required to set the different types of tools for the various sizes of machines, tool boxes, and stops, so that the time for setting any job can be quickly ascertained. In some works, the practice is to allow one standard setting time for, say, a 1 inch pin or a 2 inch bush. In such a standard time would be included time for setting all the tools used for the job concerned, irrespectively of the condition of the machine or of what the previous job may have been.

Thus, if the previous job had been a 1 inch bolt and the next job were a 1 inch pin, there would be a minimum of alteration required in the setting of tools, possibly none—the screwing dies of course would not be required—whereas, if the next job were a bush or a bolt of another length and diameter, every tool and stop may have to be changed and also the collets. The wiser plan is to allow a standard time per tool, per size of machine, and to build up the setting time accordingly as the individual tools are affected, times being given separately for fixing the tool boxes and the tools.

TOOL SETTING TABLE—TURRET LATHES. (No. 24)

Type of Tool.	Setting.	Size of Machine.			
		1	2	3	4
Turning Tool.	Tool Box in machine.				
	Tool.				
Parting Tool.	Tool Box in machine.				
	Tool.				
Dies.	Die Box in machine.				
	Dies.				

This table can be extended to cover any number of tools. The setting of the stops can be included or allowed for separately, although it is better, probably, for the time quoted for the setting of tools to be inclusive of that for setting the stops.

Time for the work done on capstan and turret lathes can be conveniently tabulated. Bolts, pins, bushes, collars, and nuts can all be satisfactorily dealt with. Much has been done on these lines, although, as stated before, this must be done to meet the requirements of each works. It is a matter of interest to note how widely the practices of the different works vary. Taking, for purposes of illustration, plain bolts of ½ inch and 1 inch diameters, 6 inches

long, made from mild steel, the following are the job rates given in different works:

Works.	Job Rates. $\frac{1}{2}''$ dia. Bolt.	$1''$ dia. Bolt.
A	14 minutes	22 minutes
B	16 ,,	25 ,,
C	20 ,,	26 ,,
D	20 ,,	35 ,,
E	31 ,,	38 ,,
F	23 ,,	40 ,,
G	$26\frac{1}{2}$,,	42 ,,

These varying job rates for similar articles reflect different finishes, materials and efficiencies of output, and go to show either, how far from efficiency the output of some works is, or how varied are the materials used and the class of finish required.

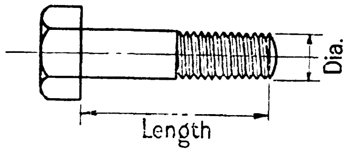
As an indication of the possibilities of removing material in machines of this class, a performance by Messrs. Alfred Herbert is worthy of mention. This took place some years before the war and consisted of the turning, screwing and parting-off of a 1 inch bolt, 7 inches long, from 2 inch mild steel black bar. The revolutions used were 302, giving a cutting speed of 158 feet per minute, the feeds were 44 to the inch, the time taken being 2 minutes $53\frac{3}{5}$ seconds.

Where large numbers of standard bolts are made it will be found worth while building up a table for bolts only, to include everything, the class of material, of course, being specified. Such a table can usually be given the form shewn on page 333.

Where the design of the bolts used varies, and where pins are a common feature of turret work, the design of the table can be arranged so that it can be used for a variety of jobs. In this case the time for turning the shank of the pin or the bolt would need to be stated as so much per inch, this amount to be multiplied in accordance with the length of the piece being estimated. A table of this kind can be found exceedingly useful; an illustration of a convenient form is given on page 334, but this can be modified to suit particular requirements. A similar table could also be built up for nuts, washers and collars.

Another useful general table will be one to give the times for the parting-off of pieces from plain bar of different diameters and classes of material. Such a table can usefully be given the form shewn on page 335. It will be noted that one column is headed "extra for jaw chuck." This is to allow for the difference between the time required for the use of collets and hand-operated chucks. If there be sufficient work to justify it, a further table can be built up for parting-off tubes with different sizes of holes. Where short pieces are being parted-off, enabling several pieces to be done at one feeding of the bar forward, a travelling stop being carried, it is better to arrange the table so that the time for parting-off is given separately from that allowed for feeding the bar. This will render the table more elastic in its application.

BOLT TABLE. (No. 25)



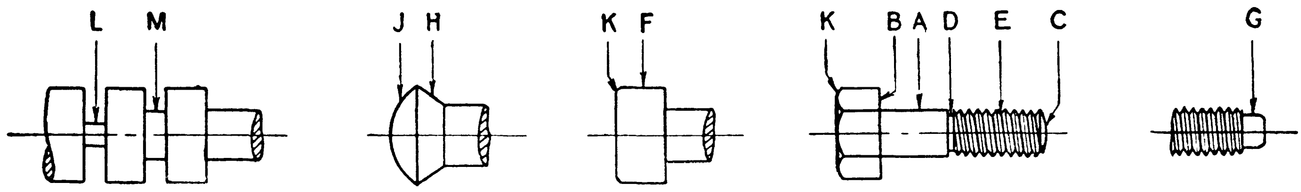
TURRET LATHES. ROLLER STEADIES. MATERIAL, M.S.
Everything included excepting initial setting of machine.

Diameter.		Length of Bolt.																					
Bolt.	Bar.	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
¼	⅝	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.5	3.7	4.0	—	—	—	—	—	—	—	—	—	—	—	—
5/16	11/16	1.9	2.1	2.4	2.6	2.9	3.1	3.3	3.6	3.8	4.1	4.3	5.0	5.3	—	—	—	—	—	—	—	—	—	—
⅜	13/16	2.1	2.4	2.7	2.9	3.2	3.5	3.8	4.1	4.3	4.6	4.9	5.2	5.5	5.7	6.0	—	—	—	—	—	—	—	—
½	1 1/16	2.5	2.8	3.1	3.4	3.7	4.1	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.6	6.9	7.2	7.5	7.8	8.1	8.4	8.7	9.1	9.4
⅝	1 5/16	3.0	3.3	3.7	4.0	4.4	4.7	5.1	5.4	5.7	6.1	6.4	6.8	7.1	7.5	7.8	8.1	8.5	8.8	9.2	9.5	9.8	10.2	10.5
¾	1½	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.4	6.8	7.2	7.6	8.0	8.4	8.8	9.2	9.6	10.0	10.4	10.8	11.2	11.6	12.0	12.4
⅞	1¾	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.0	7.5	7.9	8.3	8.7	9.1	9.5	9.9	10.3	10.6	11.0	11.5	11.9	12.3	12.6	13.0
1	2	4.9	5.2	5.6	6.0	6.4	6.8	7.2	7.6	8.0	8.4	8.7	9.1	9.5	9.9	10.3	10.7	11.1	11.5	11.9	12.3	12.6	13.0	13.4
1⅛	2¼	5.8	6.3	6.7	7.1	7.5	8.0	8.4	8.8	9.2	9.7	10.1	10.5	10.9	11.4	11.8	12.2	12.6	13.1	13.5	13.9	14.3	14.7	15.2
1¼	2⅜	6.8	7.3	7.7	8.2	8.6	9.1	9.5	10.0	10.4	10.9	11.3	11.8	12.2	12.7	13.1	13.6	14.0	14.5	14.9	15.4	15.8	16.3	16.7

BOLT AND PIN TABLE. (No. 26)

FOR USE ON TURRET LATHES WITH ROLLER STEADIES.

Material, M.S.



Dia. of Bolt.	Dia. of Bar.	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.	M.	N.	O.	P.	Q.
Inch. $\frac{1}{4}$	Inch. $\frac{5}{8}$	.22	.09	.1	.1	.19	.12	.1	.12	.45	.12	.14	.1	—	.15	.1	.1
$\frac{5}{16}$	$\frac{11}{16}$	.48	.09	.1	.1	.2	.15	.1	.15	.48	.15	.17	.1	—	.15	.1	.1
$\frac{3}{8}$	$\frac{13}{16}$	.55	.11	.1	.1	.21	.21	.1	.2	.53	.17	.23	.16	—	.15	.1	.1
$\frac{7}{16}$	1	.59	.16	.11	.1	.21	.24	.1	.25	.6	.2	.34	.21	—	.15	.1	.1
$\frac{1}{2}$	$1\frac{1}{16}$	.62	.19	.11	.11	.22	.31	.1	.3	.65	.25	.39	.25	—	.16	.1	.1
$\frac{5}{8}$	$1\frac{3}{16}$	.69	.27	.12	.12	.24	.45	.15	.4	.71	.3	.57	.42	—	.18	.12	.12
$\frac{3}{4}$	$1\frac{1}{4}$	.75	.34	.14	.13	.27	.6	.16	.5	.96	.35	.80	.53	—	.2	.15	.15
$\frac{7}{8}$	$1\frac{3}{8}$	.78	.45	.16	.14	.28	.7	.17	.6	1.3	.4	1.1	.72	—	.25	.18	.18
1	2	.8	.58	.18	.15	.28	.8	.18	.7	1.6	.45	1.4	.97	—	.3	.2	.2
$1\frac{1}{8}$	$2\frac{1}{4}$	.85	.84	.2	.16	.28	1.0	.19	.85	1.8	.5	1.9	1.2	—	.35	.25	.25
$1\frac{1}{4}$	$2\frac{3}{8}$	.9	.87	.25	.17	.31	1.1	.20	1.0	2.0	.55	2.0	1.3	—	.4	.25	.25

" A "-" E " are for 1" lengths.
" F," ordinary bolt head.
" O " covers gauging.
" P " covers feeding of bar.
" Q," allow per tool used.

PARTING-OFF—TURRETS. (No. 27)

COLLETS AND LEVER FEED.

Diameter.	Square.	Hexagon.	Soft Brass.	Mild Steel.		Tool Steel.	Extra for Jaw Chuck.
				A.	B.		
.25	.177	.216	.114	.13	.15	.25	.12
.3125	.221	.271	.122	.14	.17	.29	.12
.375	.265	.325	.140	.16	.20	.34	.12
.5	.354	.433	.156	.18	.25	.44	.12
.625	.442	.541	.174	.20	.29	.51	.12
.75	.530	.649	.190	.22	.34	.61	.13
.875	.618	.758	.208	.24	.40	.72	.14
1.00	.708	.866	.224	.26	.44	.80	.15
1.125	.796	.974	.226	.31	.52	.95	.16
1.25	.884	1.08	.308	.36	.62	1.1	.17
1.5	1.06	1.30	.406	.48	.84	1.6	.18
1.75	1.24	1.52	.51	.61	1.09	2.1	.19
2.00	1.42	1.73	.63	.76	1.38	2.6	.2

In connection with the handling of bars on capstans and automatic machines, it is necessary to remember that the longer the piece being machined or parted-off, and the heavier the material in use, the greater does the handling time become as a proportion of the whole, and also the greater the wastage of bar in "short ends." Where the influence of these factors is not recognized the worker suffers on the one hand, owing to insufficient time being allowed, and the work is often delayed on the other, because of the shortage of material which prevents the number of articles required being completed.

The whole of the references made in connection with capstan work can be applied to automatic machines. There is really no difference in the method of estimating for work done in either case. Fatigue considerations will not be necessary with automatics, while gauging will be done as the machines are running. On the other hand, the practice of running several machines by one feeder, brings into prominence another factor which must be allowed for—the overlapping of machines when, say, tool attention or new bars are required at the same time. Where the pieces being made are short in length this latter factor has comparatively little weight, but it needs to be borne in mind.

As a matter of common practice, however, it will be found that while the longer capstan operations are often estimated, those of short duration and automatic work are frequently not estimated at all, the time taken under observation being used as the basis for production estimates without any check. This is largely due to the old fallacy that the real index of the value of work is the time taken, and more particularly with automatic machines, the observed time per cycle is often accepted blindly, under the impression that there being no idleness of workers reflected therein, the time taken must be right.

What often happens, either because the machine setter has been careless or has deliberately tried to deceive the estimator, is that a machine is set so that the slow cutting traverse is brought into operation before the tool engages with the material, or a slower feed or speed is used than is necessary, this being altered as soon as the job has been " timed." The possibility of this being done is recognized in many shops and the setting is often checked, but the logical plan is to estimate the time required for cutting and for the various movements, and to check the rate of output given with that estimated. Where the relative rate of movement is controlled by cams, it is a question of ensuring the use of the right feeds and speeds.

It is a matter of some interest that such large differences are accepted, quite often and without question, between the output from capstans and automatic machines. Under some circumstances it is conceivable that output from automatic machines will be obtained at a lower rate than from capstans, but apart from the fact that the automatic machine does not get tired as does an operator, it is but logical to expect that the net rate of output from both types of machines will be somewhat similar. Generally this is not the case, and the value of automatics is often thought' and in fact found to be, in their faster production rather than in the reduced labour cost, the result of several machines being attended to by one feeder.

With light operations, it is not illogical to expect that the rate of output from capstans would be slightly larger than from automatic machines if only because of the need to avoid undue shock in the reversal of motions with the latter ; with capstans, the handling of the machine is done with variable speed and undue shock is consequently avoided. Really, some light machines are handled with almost marvellous dexterity by the operators and at a rate which is quicker than automatic machines could safely be run.

Wherever this fact is appreciated, the output from capstans is likely to be of a much more efficient character than would otherwise be the case, and a comparison on these lines is much to be recommended.

The decision as to when the engine lathe, the capstan or the automatic machine should be used is a matter for some discussion. While all operations which can be handled on automatic machines can be accommodated on capstans or on engine lathes, and all operations for which the capstan is adapted can be done on lathes, there are a large number which, because of their nature, are restricted to the lathe, and others which, owing to their quantity, are more fitted for being handled on one of these machines than on another, and some logical method is necessary of deciding which machine should be used for given operations and quantities.

Two factors are involved, (1) the cost of tools and equipment for the operation, (2) the combined cost of setting the machine and

of performing the operation. Generally speaking, the time required for preparation is shortest with lathes and greatest with automatic machines; similarly, the cost of tools is less with the lathe than with the capstan, and with the capstan than with the automatic. The cost of tools is not exactly a matter for discussion in this work; it is an initial amount and will be decided by the works management. Quantities, however, are always likely to be variable, and are an important consideration when deciding when a batch of work is small enough to justify the use of the more easily set but more expensively operated machine.

Generally speaking, with small quantities, the question is approached from the opposite standpoint. The attitude often adopted is that the use of the engine lathe is likely to be right because it can be quickly set, due regard is not being given to the possibilities of cheaper production from capstans and automatics, and, if there be a doubt, the machine which is more easily set but more expensive for labour is likely to be used. The point may appear to be a small one, but in a very large number of cases, where questions of quantity are involved, decisions are made on somewhat superficial grounds, and not on the fundamental one of the actual cost of setting and manufacture. In some works, rules exist on the basis of quantities, as, for example, less than double figures, 9 and under, the lathe to be used; two figures but not four—10 to 999—the capstan to be used; four figures and above, the automatic machine to be used.

While such a rule may have its advantages, numbers do not convey a sufficiently correct idea as to the relative value of the work involved; neither, on the other hand, will the estimated time, only, enable the whole of the facts to be weighed up. The relative cost of machine setting per unit of production will be affected by the number to be done, and, where a man both sets and operates the machine, the decision as to which machine to use is a simple one to make. On the other hand, however, when machine-setters are employed, the question arises as to the number of machines which can be efficiently dealt with by 1 man. This number is affected by three factors:

1. The length of time required to set the machine.
2. The time the total quantity takes to produce.
3. The time involved in tool and machine adjustment—attendance—during manufacture.

The varying influence of these factors, as regards the number of machines which can be looked after by 1 machine-setter, can be dealt with by the use of the following formula:

$$\text{No. of machines per machine setter} = \frac{\text{setting time} + \text{operating time per batch}}{\text{setting time} + \text{attendance}}.$$

Thus, if the time for setting be 1 hour and that for attendance be equal to 10 per cent. of the operating time, and this latter be

5 hours per batch of work done, then the maximum number of machines which could be dealt with by 1 man would be 4.

$$\text{Setting time} \qquad = 1 \text{ hour.}$$

$$\text{Attendance} = \frac{5 \text{ hours}}{10} \qquad = \cdot 5 \text{ hours.}$$

$$\text{Setting time} + \text{operating time} = 6 \text{ hours.}$$

$$\text{No. of machines } \frac{6}{1.5} \qquad = 4 \text{ machines.}$$

In these figures nothing is allowed for overlapping, that is, two machines requiring attention at the same time; for this purpose it is desirable to make the attendance factor a liberal one, as, say, 15 or 20 per cent., when 10 per cent. per individual machine is otherwise sufficient. Examples are given of the effect of the two factors of setting and attendance on the number of machines which can be worked.

	Time per Batch in Hours.			Maximum number of Machines.
	Setting.	Operating.	Attending	
Attendance time, 10 %	1	2	.2	2.5
	1	5	.5	4.0
	1	8	.8	5.0
	1	12	1.2	5.9
Attendance time, 15 %	1	2	.3	2.3
	1	5	.75	3.4
	1	8	1.2	4.0
	1	12	1.8	4.6
Attendance time, 10 %	2	6	.6	3.0
	2	10	1.0	4.0
	2	20	2.0	5.5
Attendance time, 15 %	2	6	.9	2.7
	2	10	1.5	3.4
	2	20	3.0	4.4

By splitting up machine-setting in this manner it is possible to obtain a greater efficiency of expenditure and output than where numbers in a batch only are used as a basis, and, at the same time, where jobbing work is concerned, estimating can be done on a more reliable basis.

While the influence of short batches and of the amount of attendance called for—this latter being dependent upon the class of material being worked upon and upon the accuracy of finish

required—can be clearly seen, there is another factor also which should have consideration in deciding the class of machine to be used in this case, namely, that of depreciation and interest. The real cost per piece is the criterion, and this cannot be known unless depreciation and interest on the machine used are included.

Really, in cases of this kind, it is necessary that hourly rates for machines should be drawn up which will include all the items of oncost which are involved by the use of the individual machine. This is particularly the case if the product manufactured be affected by keen competition, and when this is done, the decisions made can be based on actual facts rather than ill-considered opinions.

If, for purposes of comparison, however, the influence of depreciation and interest, only, on the machine used be considered, the point can be made sufficiently for its importance to be realized. Let it be assumed that the cost of a lathe, a capstan, and an automatic machine, each suitable for handling the same job, be respectively £150, £300, and £600, and that the depreciation and interest on these is equal to 10, 12½ and 15 per cent. of the original cost , then, on an assumed activity of 50 weeks per annum and 40 hours per week, these amounts must be spread over 2000 hours. This will mean that the hourly rates for depreciation and interest and the total labour rates, including machine-setting and operating, will be as follows when men running individual machines are paid 1/- per hour, capstan and automatic machine setters are paid 1/1 and 1/2 per hour respectively ; when capstan operators are paid 8d. per hour and automatic machine feeders are paid 6d. per hour.

Type.	Cost.	Machines Attended by one Man.		Hourly Rates per Machine in Pence.			
				Depreciation and Interest.	Labour.		
		Set.	Operated.		Setter.	Operator.	Total.
Lathe	£150	1		1.8	12		13.8
Capstan	£300	1		4.5	12		16.5
		2	1		6.5	8	19.0
		3	1		4.33	8	16.83
		4	1		3.25	8	15.75
		5	1		2.6	8	15.1
		6	1		2.16	8	14.66
Automatic Machine	£600	1		10.8	12		22.8
		2	6		7.0	1	18.8
		3	6		4.66	1	16.46
		4	6		3.5	1	15.3
		5	6		2.8	1	14.6
		6	6		2.33	1	14.13

It is only when the basis of the hourly cost of running machines is known that, anything like a true idea of the real position can be

gleaned. It is better, really, if other expenses incidental to the running of machines of this class be also included, so that the figures would be more closely accurate but, as they stand, it will be apparent that to run 2 or 3 capstans, with a machine-setter and an operator for each, is more expensive than to use a higher class of labour and no machine-setter, excepting of course a lower rate of wages be paid to the operators than that used above.

Further, it is actually cheaper at the rates used to run 2 automatic machines with one machine-setter, provided the feeder attends to 6 machines, than it is to run 2 capstans with 1 machine-setter and 2 operators; and, bearing in mind the fact that the output from automatic machines is usually higher than from capstans, the resultant production will be correspondingly cheaper. In this respect plain jobs only are referred to, that is, jobs for which special tools are not required.

If for purposes of illustration it be assumed that batches of plain bolts are required as follows, 10, 25, 50, 100, 200; that the estimated time for the lathe, the capstan and the automatic machines be 30 minutes, 5 minutes and 4 minutes respectively; that preparation times of 20 minutes, 1 hour and 2 hours are required for the machines in the order given, and that 12½ per cent. on cutting time is required to cover overlap, the number of machines which could be attended to by 1 machine-setter and also the resultant cost will be as follows:

Type.	No. of Machines Set.	Total Hourly Rate.	Total Time Taken. Hours. Mins	Cost Each for Quantities Quoted. 10	25	50	100	200
Lathe - -	1	13.8	5 20	7.36				
	1	16.5	1 50	3.03				
	2	19.0	3 5		2.34			
Capstan -	3	16.83	5 10			1.74		
	4	15.75	9 20				1.47	
	5	15.1	17 40					1.33
Automatic -	1	22.8	3 20		3.04			
	2	18.8	5 20			2.00		
	3	16.46	8 40				1.43	
	4	15.3	15 20					1.17

It will thus be seen that on the basis of the values used in the foregoing statement, the use of automatic machines can be profitable even with comparatively short runs. The utility of a statement of this kind, however, is that the possibilities of the respective machines, together with the cost, are brought into a more correct perspective. The setting times used, as also the percentage allowance made for attendance, will require modification for the different classes of machines and materials used, and also as the nature of the job calls for closer watching, but the principle remains the same.

Where a method of this kind is used, particularly when job rates are fixed beforehand, tables can be made up shewing, for the different job rates and setting times, the number of machines which machine-setters can be expected to look after satisfactorily. Owing to the varying amount of the setting required, because of the influence of the previous job as to the tools, etc., used, no hard and fast rule can well be laid down, but the guide is useful.

CHAPTER XXX

PRODUCTION ESTIMATING. GRINDING

GRINDING, although one of the oldest processes known, is one of the latest entrants into the field of engineering manufacture as a serious competitor with other methods. At one time confined almost entirely to the sharpening of tools and to "fettling," its use has gradually been extended to the finishing of hardened and then to that of soft steel parts, until its value as an accurate and economical method of attaining surfaces of high finish, in many classes of work, is almost universally recognized. At the same time, possibly because of its comparative infancy, there is a greater difference between the outputs obtained from grinding and those possible, than is the case with most other processes, and the estimating of rates of output reflects this fact.

Grinding is divided, principally, into three classes, cylindrical, horizontal surface, and vertical surface grinding, each of which is accompanied by its own problems as regards estimating, although the principal consideration, the amount of material to be left for removal, is common to all.

Where rate of output is concerned, it is noted that grinding machine manufacturers themselves are somewhat chary of giving rules by which time can be estimated, although this is interpreted as an indication of the difficulties arising out of the influence of the varying factors, rather than a lack of knowledge or of unwillingness to be of assistance. Unlike the cutting of metal with the single point tool, there are factors other than the cutting speed, depth of cut and feeds per inch to be considered. There are the additional questions of wheel speed and grade. When either of these is unsatisfactory undue heat may be generated, causing distortion of the work, or the wear on the wheel may be so great as to make the expense prohibitive.

It is probably true that each firm's grinding proposition is peculiarly its own and should be the subject of separate observation and test, all the factors being taken into consideration. This is not always sufficiently appreciated, and output is quite often estimated by the use of formulae and data which are entirely second-hand, for the basis of which no knowledge is available. This is not

satisfactory, and in the event of an estimated output being queried as to the possibility of its attainment, no intelligible defence can be put forward.

With grinding, as with all other classes of work, the basis of job rates should be the proved output possibilities as demonstrated in those works concerned. In the event of there being no member of the staff with sufficient knowledge of the process for the results of the tests made to be accepted with confidence, it would be infinitely more satisfactory for assistance to be sought from the suppliers of the grinding machines, or the wheels in use, than to grope in the darkness with incompetent men, accepting the results of trial or mechanical observation at their face value, as is so often done.

One of the first requirements to be laid down is the amount of material to be left for removal. This is a matter upon which some grinding machine experts are not yet fully satisfied, and, bearing in mind that the test of economy is the ultimate cost of the job, some propositions have been put forward in which the possibility of success was not present.

The author remembers a case of a firm who offered to fix a grinding machine at their own expense, the same to be purchased if they succeeded in demonstrating that grinding was cheaper than the rough and finish turning of twist drills. A really fine performance was put up and a good case was being made out for the proposition, but, when the amount of wear of the wheel was taken into consideration, it was found that for each twist drill shank roughly ground, the wheel cost was rather more than 2 pence each. As soon as this was included in the cost the case for grinding was lost. This is not an argument against grinding, but rather a pointer that there is a limit to its application as an economical method of removing material and to the necessity of considering all the known factors when making decisions.

With reference to the amount of material to be left for removal by grinding, as indicated above, attention is being given to the use of grinding for roughing as well as for finishing purposes. The technicalities of grinding cannot be discussed here, but, where grinding throughout has been proved to be the cheaper method, obviously that method should be adopted ; when roughing with the single point tool is the cheaper, the question is then one as to how close to the finished size the roughing may be taken without the roughing nature of the operation being departed from, and without the grinding operation being prejudiced for setting, by too little material being left.

This aspect of the question deserves more attention. Much time can be wasted in both directions, and turners are sometimes called upon to leave almost finished surfaces in roughing operations, because of the tolerance limits laid down. With cylindrical work, for example, the aim should be to enable the turning operation to be purely a roughing one ; thus, while, in theory, the amount

left on for grinding should be measured at the bottom of the cut yet, seeing coarse feeds ought to be used, it would be better to allow wide tolerances and to measure over the tops of the feed marks. This would not actually determine the minimum amount of material to be left on for grinding but, on the other hand, the turner would not be tied to such fine limits or slow feeds.

The author remembers cases where on large diameters—12 inches upwards—the feeds used in rough turning were 4 to the inch and the difference between the diameter at the top and the bottom of the feed marks varied from .07 to .1 of an inch. It became the rule to leave .1 of an inch, and dependent upon the turner's interpretation as to whether this amount was to be measured from the top or the bottom of the feed marks, the amount of material left on for grinding varied accordingly. The variation, consequently, was great and the amount of material left for grinding was generally too much.

With work of small diameter, the question of the method of measurement and of the feed becomes of less importance, the latter being controlled by the rigidity of the work being done. Length requires to be taken into consideration, and the greater the length, relative to the diameter until the limit is reached, the more material will be required to be left because of the difficulty and consequent inaccuracy of the turning. Thus two jobs, $\frac{1}{2}$ inch and 2 inches in diameter, respectively, would cause no difficulty either in turning or grinding if their lengths were 6 inches only, but, if the length were extended to 20 inches, the turning of the $\frac{1}{2}$ inch diameter job would have become difficult because of its springiness, whereas the 2 inch diameter job would not be affected. It is well to keep this factor in mind when deciding the allowances which shall be left for grinding, and if these be based on turning becoming difficult as the lengths of the jobs exceed, say 10 to 15 diameters, according to its class, such a table should prove to be consistently satisfactory. At the same time, the provision so made is often ignored in the shops, and it is not improbable that more has been made of this factor than its importance justifies. The shorter the job the more rigid it is, and from this one standpoint it could be argued that more material could be left for grinding on short than on long jobs.

The object being to make the turning a purely roughing operation, this cannot be done excepting the tolerances are big enough; on the other hand, there is no virtue in leaving more material for removal by grinding than is necessary. The best plan is to quote minimum diameters and to allow big tolerances, specifying at the same time the roughing feed to be used on the lathe.

The next considerations are those of feed and depth of cut. It will be obvious that the strength of the job will have to be considered in this respect. The longer the job, the less rigid does it naturally become, and stays are required accordingly. Stays require

setting and, seeing time will be required for each stay set, some formula or standard is needed to control the allowance, as, say, one stay for every 10 diameters in length but not less than one for every 3 feet. If desired a table could be built up for this purpose ; the grinder would find it useful. If done for estimating purposes the references could be either in terms of " stays " or of total time for the various lengths and diameters of jobs.

The rate at which material can be removed is a matter which is open to much variation. Many different formulae are in use the basis often being unknown. The objection to this is that estimating is done blindly, and for this there is no logical reason.

The recommendation of grinding experts is that the widest wheel a job will stand should be used and that the most suitable feed to use is two thirds the width of the wheel. It follows that the width of wheel which can be efficiently used can be controlled by the feeds with which machines are supplied. Wheel speed is not a matter for consideration in this work, although, seeing the output will be affected by the speeds used, both for wheel and work, the estimator should have a knowledge as to what speeds are suitable.

The ideal peripheral speed of grinding wheels is generally agreed to be about 6000 feet per minute, although in practice this is often found to vary as much as 50 per cent. downwards ; it is a factor to which less attention is given than is desirable.

Opinions and also practice as to work speeds vary even more than in the case of grinding wheel speeds ; work speeds range from 25 feet to 80 feet per minute for mild steels. The slower the work speed, then, the slower will be the feed used. As regards output this can be counteracted sometimes, to some extent, by the use of wide wheels where the machine is provided with suitable rates of feed, although this would not overcome the objection of the slow work speed. The avoidance of local heating undoubtedly points to high rather than to low work speeds.

The depth of cut which can be taken is a factor which can be ascertained. This is variable, but often in ordinary practice does not exceed .0005 of an inch, and .00025 of an inch is more common. Heavier cuts can be taken in the early parts of the operation, and it is necessary to bear this in mind in working up factors for estimating. If a shaft 2 inches diameter, 18 inches long, is to be ground and .032 of an inch has been left for grinding, then, if the average amount of material which can be removed from the diameter, per cut, is equal to .0006 of an inch, 54 cuts will be needed to obtain the finish required. The use of a 2 inch wheel at a traverse of two thirds the width would mean .75 of a feed to the inch. A factor built up on this basis would be arrived at as shewn below, the formula used being the same as for turning. The work speed used will be presumed to be 50 feet. Then, allowing the length of traverse to be the length of the job plus the width of the wheel—

in this case presumed to be 2 inches—the grinding time will be as follows :

$$\text{grinding time} = \frac{20 \times 54 \times .75}{96} = 8.44 \text{ minutes,}$$

or approximately .42 minutes per inch of traverse.

If a 3 inch wheel were used and the depths of cut taken were the same, then, in using a feed equal to two thirds the width of wheel, the feed would be 2 inches per revolution of the work or .5 of a feed per inch, and the time taken would be reduced to 5.9 minutes, or for the 21 inches of traverse, .28 minutes per inch.

In the case of small diameters, the rate of work or wheel traverse required per minute to give a feed equal to two thirds of the width of wheel, may be greater than those with which some machines are provided, and this fact must be provided for in the building up of the various factors. For example, to grind material .75 of an inch in diameter, with a wheel 2 inches wide and using a work speed of 50 feet per minute, the traverse across the wheel at a feed of two thirds the width of wheel would be at the rate of 340 inches per minute, for which rate the author has yet to see a machine made.

With the possibilities of machine output checked and provided for, and with maximum and minimum grinding allowances fixed, it is possible to build up factors and, if desired, tables from which the approximate grinding times for the different diameters can be obtained. It is wise to keep the time for gauging and handling outside the grinding factors, although, of course, these can be stated separately. Contingency allowances for wheel dressing, etc., can be included in the factor, these being dependent upon the amount of grinding done, and, consequently, are reflected in the time taken. A sample table on the next page gives factors for use with wheels of different diameters and for the removal of the amounts of material specified.

Gauging is such a variable item that one rule can hardly cover the many different requirements, diameters and lengths. It must not be forgotten that the gauging of ground work, with micrometers, can be done only when the machine is stopped ; the time allowance must be sufficient to cover this. One method of building up a scale of gauging allowances is also shewn in the table.

Of course, if desired, a table could be prepared giving factors for different diameters and also for the removal of different amounts of material ; alternatively, for the complete grinding of various diameters of specified lengths, the material allowances being fixed. Whatever method of tabulation is adopted the basis of the times quoted must be estimated on the lines laid down ; if the times are arrived at as the result of observation, the various results should be compared to make sure they are consistent with each other. There is a risk in using tables based on the removal of varying amounts of material, excepting some rules be laid down as to the conditions under which the different amounts should apply. If

this is not done the matter will be left open to the discretion of the various people handling the turning and grinding, and the results are likely to become unsatisfactory.

Surface Grinding. There are two kinds of surface grinding; one done on the reciprocating machine of the planer type where the periphery or cylindrical face of the wheel is used, the other, frequently known as "vertical" grinding, where a cup or plain

GRINDING TABLE. (No. 28)

CYLINDRICAL. EXTERNAL.

For Unhardened Mild Steel.

Diameter in Inches -		.5	.75	1.0	1.25	1.5	2.0	2.5	3	4	6	8	12
Material to be removed.	Minimum	.005	.006	.008	.010	.010	.012	.012	.014	.016	.018	.020	.020
	Maximum	.015	.020	.030	.035	.035	.040	.045	.050	.055	.060	.070	.080
Rough turning feeds -		40	32	32	24	24	24	20	20	16	12	10	8
Width of Wheel.	Class of Fit.	FACTORS.											
1″	A	.562	.562	.562	—	—	—	—	—	—	—	—	—
	B	.656	.656	.656	—	—	—	—	—	—	—	—	—
2″	A	—	—	.281	.312	.222	.332	.384	.515	.572	.921	—	—
	B	—	—	.327	.372	.269	.404	.480	.651	.737	1.04	—	—
3″	A	—	—	—	—	—	.257	.300	.347	.388	.560	.732	1.08
	B	—	—	—	—	—	320	.377	.441	.500	.701	.895	1.28

Grinding time = (length of job + width of wheel) × factor.
Allow setting in accordance with nature of job.

Gauging.			Diameter - -	.5	.75	1.0	1.25	1.5	2.0	2.5	3	4	6	8	21
	Class of Fit.	A	Per Size -	.2	.2	.2	.25	.25	.25	.3	.3	.4	.5	.7	1.0
			Per Foot	.2	.2	.2	.2	.2	.25	.25	.25	.3	.4	.5	.6
		B	Per Size -	1.0	1.0	1.0	1.2	1.2	1.2	1.4	1.4	1.6	2.0	2.5	3.0
			Per Foot-	.5	.5	.5	.6	.6	.6	.7	.7	8.	.9	1.0	1.0

Stays. Allow 1 stay per 10 diameters in length; not less than 1 stay per 3 feet.
Allow 2 minutes per stay setting.

wheel is used, grinding being done on the edge or side. Much of the work done is suitable for either class of machine, but, owing partly to its initial cost and the rapidity with which the work is "eaten up" by the vertical machine, some firms say they cannot afford to purchase it because it would stand idle for such a large proportion of its time. This, of course, can be true, but such reasoning is often unsound. The considerations necessary with surface grinding are similar to those for cylindrical work. Generally speaking, however, with the reciprocating machine the

wheel and the work speeds are slower than those used with cylindrical work. This is due in part to the wheel used being smaller in diameter, requiring correspondingly higher spindle speeds, and further, to the reciprocating motion of the machine.

To estimate rate of output it is necessary to find the factor of the machine as with planing machines. The work speed is of more moment with machines of this class than is the case with cylindrical work. The design of the machine can affect the speed possible and some machines are to be found running as slow as 20 feet per minute. The aim should be to run at not less than 30 feet, which gives a cutting factor for speed of 360. This factor divided by the length of stroke required will give the number of strokes per minute, each movement counting a stroke. In the case of some surface grinding machines, the design is such that the feed is taken at one end of the stroke only, really making one stroke in two in the nature of an idle stroke. This is a feature which the uninformed non-technical machine buyer overlooks.

The feeds used will vary with the width of wheel, but 10 or 12 feeds for roughing and 16 to 24 feeds for finishing are known to have given good results, although, in the latter case, finer and coarser feeds are used.

The depths of cut taken on surface grinders of this type are heavier than on cylindrical work, from .001 to .003 of an inch being taken. In estimating it is well to allow for the removal of the material at a definite rate as regards the depth of cut, and to allow one or two extra cuts over as spring cuts, so as to obtain accurate faces. Estimating is done precisely as with shaping, the formula being

$$\text{grinding time} = \frac{(\text{width of job} + \text{width of stone}) \times \text{cuts} \times \text{feeds}}{\text{strokes per minute}}.$$

If desired, a factor can be readily calculated per thousandth per square inch or foot of area covered. Thus if .01 of an inch is to be removed from a surface $5\frac{1}{2} \times 5\frac{1}{2}$ inches, requiring, with a wheel .5 of an inch wide, an area of 6×6 inches to be covered, that means an over-run of .25 of an inch each end, and the depth of cut taken be .0015 of an inch, then, with a work speed of 30 feet per minute, the rate per thousandth per square inch would be obtained as follows :

$$\text{grinding time per thousandth} = \frac{\text{width of traverse} \times \text{cuts} \times \text{feeds}}{\text{strokes per minute} \times \text{area in square inches} \times \text{thousandths}},$$

then $\dfrac{6 \times 7 \times 12}{60 \times 36 \times 10} = .023$ of a minute per square inch per thousandth.

A factor for finishing only is then necessary, and, calculated as before, allowing two cuts over at 18 feeds, the factor per square inch would be .1 of a minute. When the amount of material to be left for grinding is fixed, as it should be, the two factors together with the contingency and wheel-dressing allowances can be combined.

Thus if the standard allowance were .005 of an inch the combined factor would be as follows :

Allowance per thousandth per sq. in. × thousandths = .023 × 5	= .115
Allowance for finishing - - - - - - - -	= .1
Total per square inch of area of stroke and traverse - -	= .215
20 % added for contingencies - - - - - - -	= .043
Combined factor per square inch - - - - -	= .258

To obtain the rate of production by the use of a factor of this kind it will be necessary to add the time for setting and gauging ; these cannot be specified excepting for individual jobs or known conditions. In some instances gauging is practically unnecessary ; in others it is a most important point.

Vertical Grinding. While vertical grinding is the latest of the three types to be introduced, its value has been speedily recognized and its use is being extended in many directions. Vertical grinding machines are made principally in two types, one with a circular movement of the table, the other reciprocating. There is no doubt that for certain classes of work the old method of surface grinding with the periphery of the wheel is being displaced. With vertical grinding there is but one motion of the work under the wheel, and that is circular or reciprocating as the case may be. The cut is fed in a downward direction, and the time for grinding is a matter of the amount of material left for removal, the depth of cut which can be taken and the number of revolutions or strokes of the table which can be taken per minute. This can be expressed by means of the following formula :

$$\text{grinding time} = \frac{\text{amount of material to be removed}}{\text{depth of cut} \times \text{revolutious or strokes per minute}}.$$

Thus if .02 of an inch of material were left for grinding and the depth of cut which could be taken were .00025 of an inch and the strokes taken per minute were 10, the grinding time would be as follows :

$$\text{grinding time} = \frac{.02}{.00025 \times 10} = 8 \text{ minutes.}$$

To this amount, the time for gauging, setting, and for contingencies would need to be added.

In practice, the formula, as given above, would probably be simplified by the mental conversion of the depth of cut to cuts per thousandth of an inch, the amount of material to be removed, in thousandths, being multiplied by this figure. Thus the removal of .00025 of an inch means 4 cuts per thousandth, and with .02 of an inch to be removed, 80 cuts would be required—20 × 4 = 80 cuts ; then

$$\text{grinding time} = \frac{80}{10} = 8 \text{ minutes.}$$

The distribution of the pieces on the table for grinding is controlled by the diameter of the wheel used, and the pieces must be

so arranged that they are overlapped by the wheel, otherwise the result of the grinding will be pieces of irregular thickness. The distribution of the pieces as regards the surfaces to be ground is worthy of attention, and it will be obvious that, beyond a certain point, the larger the area to be ground the less the depth of cut which can be taken or the slower must be the speed that is used.

This suggests that, for tabulation purposes, a basis of area would be appropriate, the basis to be time per thousandth removed per square inch. It may be found advisable to provide separate factors for roughing and finishing. Different factors will also be required for areas of different sizes,

Cutter Grinding. The grinding of the teeth of milling cutters and reamers is a vexed question in some works, and there is no doubt that output in this respect is often low. Provided a suitable check is kept upon the number and the condition of the cutters sent to be ground, work of this description, whether new or for re-sharpening, can be given job rates. The basis should be the length and number of teeth, grinding factors per lineal inch of tooth being fixed to suit the various classes of work. On the assumption that an average is satisfactory in this case, tables could be built up giving the total times for the various types and sizes of cutters.

This practice can be extended to the grinding of tools of various kinds and also to the re-sharpening of twist drills. The important point to watch is that tools are not sent to be ground which do not need it. This has been known to be done, the grinder sharing the resultant spoils with his confederate.

CHAPTER XXXI

PRODUCTION ESTIMATING. FITTING

FITTING is a general term and covers the carrying out of those operations necessary to bring components, whether machined or not, to such a condition that subsequent assembly is possible. In practice, the work of assembly is often linked up with fitting, and it is dependent upon the nature of the work, and the quantities, as to whether this is desirable. If, by machining processes, the dimensions specified could be produced exactly as required, and the class of finish were entirely satisfactory, the fitter, as such, would not be known. Broadly speaking, the fitter exists because the product of machine shops is not good enough—there are a few exceptions—the components requiring adjustment or correction to enable them to be used, and it may be said that the ultimate test of machine shop efficiency is the extent to which fitting is avoided. Practice does not always reflect this view, and attention in the machine shop is often confined to rate of output and cost, independently of the subsequent cost of fitting. It has often been the experience that an extra cut in the machine, a little more attention to the method of clamping jobs down, resulting perhaps in a slightly increased machining cost, has enabled the cost of fitting to be reduced in a much greater proportion than that by which the machining cost has been increased.

The right attitude to adopt is that the fitting of machined parts is in the nature of an adjusting operation, and eventually should not be required, and that, as a first principle, all adjustment should be reduced to a minimum. True, the need for fitting cannot yet be avoided, but that does not make the necessity for it any the more desirable. The progress of machine tool design, resulting in new processes being made available and in improving the results possible from those already existing, has been most marked during the last few decades, and much work is completed on machines to-day which formerly was partly or entirely done by hand.

The possibilities of grinding and broaching, in particular, are not yet generally appreciated, and with all classes of work where these processes can be applied, the future is a big one.

The work of the fitter is usually carried out by hand, and may

include the following processes : chipping, filing, scraping, polishing, reaming, riveting, tapping, studding and marking-off. These are applied under a multitude of conditions, but the principles involved are the same. The difference between achieving the desired results on work requiring varying degrees of accuracy is largely one of time rather than of method. If, however, the output records for fitting operations were looked up, it would probably be found that these would shew widely varying results, even for the same operations, and because of this experience it has been thought, in some quarters, that rate of output cannot be estimated, except within wide limits. Unfortunately when this view has been accepted without the careful investigation required, matters have been allowed to slide, and the position has slowly and steadily deteriorated.

It is undoubtedly true, where payment by results has been attempted on fitting work, that in a number of instances the results obtained have not been satisfactory owing to the variability in the rate of output, but there has also been evidence that insufficient attention had been given to certain factors which have a controlling influence where output on fitting work is concerned.

While, generally speaking, fitting is a question of the removal of material, and, to a degree, the principles involved are not different from those which affect machining operations, the capacity of a fitter to remove material is obviously much smaller and more quickly affected by unsuitable conditions than is the case with machining. If, for the moment, the fitter be looked upon in the light of a machine, and his capacity be measured, it would be somewhat surprising to find just how overloaded his operations often are. With machine work, because of the importance of economy of time as well as of material, the amount allowed for machining is carefully considered, and one eighth of an inch is not allowed if one sixteenth will be sufficient. With fitting, however, this same care is not always in evidence, actually, although it may appear to be.

It may be definitely laid down, or may be more or less generally understood, that certain amounts of material should be left in machining for removal by the fitter, but, whatever these amounts may be, it is an all too common experience to find that these are exceeded, and the significance of such excesses are not always sufficiently appreciated. For example, if .002 of an inch are known to be sufficient to be left on a machined face to enable a good face to be scraped up, and .004 of an inch are left, then, although the amount is but 4 thousandths, it is double what is required, and the removal of the additional material must take the fitter considerably longer than as though the normal amount only were left. Excepting where close attention is given to this matter it will be found that pieces passed to the fitters to work upon vary, in the amount of work actually necessary to carry out the operation required, within limits that are truly amazing ; instances have been known where, when .002 of an inch have been required, the amounts

actually left in the machining have varied from .001 of an inch to .035 of an inch.

If the larger amounts be treated as exceptional, and .006 of an inch be considered as being more common, even this is an excess of 200 per cent., or, if its equivalent in machining allowances be taken, is comparable to supplying material with .375 of an inch to be removed instead of .125 of an inch. The importance of thousandths to the fitter is not always properly appreciated, and in a large number of cases the differences in results are not so much a reflection of the fitter's skill or energy as the amount of work really involved, due to the unsatisfactory and variable quality of the machining.

This is really a serious question, and probably there is no more fruitful line of investigation than that of the preparation of components for the fitter. Quite an important factor is the efficiency of jig design, the suitability of the locating faces used. It would appear almost, in some instances, as though the jig had application to machining requirements only. The ultimate object is economical complete cost and the final results should always be borne in mind. It is a fact, of course, that the mistakes of manufacture are usually left to be dealt with in the fitting shop. In a measure this is unavoidable, and in many cases is economically correct, but it is desirable that the faulty work so sent should be known, not only as being faulty but also as to its extent.

The necessity for tools, too, to be in good condition is an equally important factor. It should be the aim always to keep all tools sharp and efficient, but, because of the small range of a man's strength and endurance, it is doubly important with fitting operations; the use of blunt tools, taps, reamers, files, and the like is one of the most wasteful "economies" possible. This is not to suggest that the need for economy in this respect should be treated lightly. This must never be the case, but some intelligent oversight is necessary if efficiency and true economy of manufacture are to be assured.

It is thought sometimes, because fitting is purely manual work, that the bulk of the fitter himself has an important bearing on the results obtained. While there are cases where this could be true, height rather than bulk perhaps is the most likely direction in which the build of the workman would have influence. In the ordinary way, fitting is not an unduly arduous job; it calls generally for the intelligent use of skill rather than the exercise of a large amount of brute strength; even more than with machine work, skill is the factor which tells.

In dealing with the rate of output possible on operations which are done entirely by hand, the influence of the human factor is naturally more obvious than with operations which are partly or wholly done by machine. As stated elsewhere, work done is the result of a combination of at least three factors, machines and appliances, skill, and energy, and accordingly as the use of the first

mentioned predominates over the last two, the estimating of the rate of output can be based on data which is definitely provable. On the other hand, as the influence of the use of machines becomes reduced, the uncertain results of the combination of skill and energy become more manifest, and the estimating of the rate of output must be guided by data, which is the result of trial or observation rather than of purely mechanical demonstration.

Owing to this factor, the application of systems of payment by results to the work of fitting and assembly has often either been deferred or average rates of output have been used as a basis for fixing job rates, even after analytical methods have been applied to machine work. While it can be admitted that the time spent on fitting operations is likely to vary more than is the case with machine operations, this is not to say that the rate of output cannot be estimated. The fact that tenders are sought for and submitted calls for estimating, and the influence of competition makes it necessary that some fair measure of efficiency shall be secured. This at once infers the need for some standard which will enable close estimating to be done without undue risk of loss being taken. As in other instances, the setting up of a standard of output has an educational value as well as a commercial one where tendering is concerned, and, although much difference in output may be found when a standard is first applied, the tendency will be to approach that standard, which should mean a levelling up as against a levelling down, which is the position when averages only are used.

Although with hand labour operations of any kind the factors operating are the same as those which can affect machine work, their influence is felt in different degrees. With machine work, for example, where flatness or cylindricity is concerned, this is produced by the machine itself, and would be the same independently of the skill and ability of the machine attendant, while the machine, once started, calls for no further effort until the cut is over, power being supplied for the driving of same. Certainly skill is necessary in the setting of work, and of tools and cuts, and in grinding tools, but these call for comparatively little effort of a laborious kind.

With fitting, however, the efficiency and the amount of the work done reflects the skill and also the muscular effort of the fitter, a demand for which is constantly made, and this, if relaxed, may reduce or stop the output. It follows that the whole of the efforts being manual, closer attention is necessary in the preparation of work for fitting than is the case with machining, for the purpose of ensuring that the amount of work involved to complete the operation is reduced to a minimum.

Chipping. The hammer and chisel are two of the oldest of the fitter's tools. Much of the work now done on milling, slotting, shaping, and planing machines was once carried out by the use of the hammer and chisel, and some exceedingly clever work has been done therewith. Apart from constructional and jobbing work, the use of the chisel is the exception rather than the rule to-day,

although it is still used for many purposes, amongst which may be mentioned the chipping of surfaces which, because of their position or for some special reason, cannot be machined; the removal of surplus metal necessitated by the fouling of parts in assembly; the chipping of oil grooves and the cutting of clearances; of course, wherever possible and practicable, the use of the pneumatic hammer is desirable, considerable economy arising therefrom. Generally speaking, chipping with the "hard" chisel is measurable in terms of area, and the number of times the surface has to be gone over; the use of the cross-cut or round-nosed chisels is more often a question of running inches.

What needs to be established, in the first place, is the time value of the chipping of different materials by hand and by pneumatic hammers for different depths, while actually this is bound to be the product of the following formula:

$$\text{time in minutes} = \frac{\text{area in square inches} \times \text{number of cuts}}{\text{width of chisel} \times \text{blows per min.} \times \text{travel of chisel per blow}}.$$

the formula is rarely used. It is thought sometimes that to use it savours rather of absurdity, but the only logical method of analyzing any performance is in the manner in which the work is done. The value of applying the formula in this manner is that the importance of using suitable hammers and chisels is likely to be appreciated, and in the building up of data for general use the relative efficiency of each of the factors should be known. Having collected the data, this can be converted into a rate per square inch.

Plain Chipping. The chipping of plain surfaces can be done as follows:

CHIPPING TABLE. (No. 29)

Class of Material.	Depth of Cut.	Minutes per Square Inch.	
		Hand.	Pneumatic Hammer.
Mild Steel - - - -	$\frac{1}{16}$	3.0	1.3
	$\frac{1}{8}$	5.0	2.0
Cast Iron - - - -	$\frac{1}{16}$	2.5	1.0
	$\frac{1}{8}$	4.0	1.5
Gun-metal - - - -	$\frac{1}{16}$	2.75	1.1
	$\frac{1}{8}$	4.25	1.7
Steel Casting - - -	$\frac{1}{16}$	3.5	1.5
	$\frac{1}{8}$	5.5	2.2

Chipping Oil Grooves. Oil grooves are called for on journals, in bearings and on flat faces. On journals, oil grooves can, usually, be conveniently cut on milling machines or in the lathe; in bearings, they can also be cut on the lathe. Many oil grooves, however,

because of the small quantities required or the comparatively large amount of setting involved, can be more economically cut by hand or pneumatic hammer. The time for cutting can best be dealt with on the basis of lineal inches for grooves of different widths. Where abnormally deep grooves are called for, depth as well as width would have to be considered.

OIL GROOVES—CHIPPING. (No. 30)

Class of Material.	Width.	Minutes per Lineal Inch.	
		Hand.	Pneumatic Hammer.
Mild Steel - - - -	$\frac{3}{16}$	2.5	1.3
	$\frac{3}{8}$	3.5	1.7
Cast Iron - - - -	$\frac{3}{16}$	2.0	1.0
	$\frac{3}{8}$	2.7	1.3
Gun-metal - - -	$\frac{3}{16}$	2.0	1.0
	$\frac{3}{8}$	2.7	1.3
White Metal - - -	$\frac{3}{16}$	1.7	.9
	$\frac{3}{8}$	2.2	1.0

Chipping—Cutting off. In some instances, surplus material must be left for the purpose of handling or because the conditions of assembly make it impossible for close dimensions to be given; it may be, again, that material must be removed to form clearances and that this can be more readily done by hammer and chisel than by machine; in some cases, a line of holes is drilled and the surplus material cut off by hammer and chisel and dressed off afterwards. This happens most frequently with plate work, and a formula (No. 31) on the following lines will be found of use:

$$\text{Time in minutes} = \text{lineal inches} \times \text{thickness in inches} \times 10.$$

If on plate of 1 inch thickness there are 10 inches of surplus to be removed, the estimated time for so doing would be 100 minutes. With very soft steels a reduction of this amount is possible.

Chipping—Filing—Bedding. The chipping, filing and bedding of faces is a feature of heavy, marine, and constructional engineering practice rather than of ordinary engineering. It is called for more in ship-fitting and boiler-making perhaps than in any other class of work, and is one of the exceptions where the need is not the result of inaccurate machining but rather of the difficulty of machining at all. Because of the comparatively thin plates used in the building of ships and boilers, and in some cases of the impractic-

ability of machining these, even if they were thick enough to withstand same, steel or metal pads have to be fitted for the purpose of stiffening the plates and also for carrying steam, water and other fittings, or to form suitable supports for the clamping of machinery and the like.

Owing to the necessity for avoiding distortion in the structure, setting up unnecessary strains, these pads have to be bedded to the decks, partitions, hull, or shell as the case may be, and this work must be done by hand. These pads of course can be machined on each face, and where flat faces are required there is no undue difficulty; but where, as on the hull of a ship or the shell of a boiler, the surface to which the pad is to be bedded is not flat, the amount of work involved is not only greater but is of a more difficult character.

In such cases, after the surface to which the pad is to be fitted has been smoothed, burrs, scale and bruises or other irregularities removed, the pad is "offered" to its relative position, and with hermaphrodite calipers,—"moffs"—the contour is marked off, after which it is roughly machined on the shaping or slotting machine, or the lathe, as may be found most suitable.

The actual work varies widely in accordance with the requirements which have to be met. In one case, a pad may have to be fitted only, no position of face being required; in others, the face may have to be finished correct to level in either one or two directions, in addition to which there may be the further factor of the contour of the faces.

The positions also, in which pads of this kind are required vary considerably; a pad may be required for the top of a deck or the underside of the deck above; the one easy to get at, the other being "uphand," and exceedingly awkward; there may be plenty of elbow room in each case, or space may be so restricted that the work is difficult as well as awkward to get at. Work of this kind has sometimes to be done lying on the back, sitting, kneeling, or standing; the last three may take place either on the deck or on a scaffold.

Whatever may be the conditions to be met, the basis on which output must be estimated is obviously one of area, and square inches form the most convenient unit. The rate of output in different shipyards varies almost as much as the conditions themselves; but it is not wise to accept, as a matter of course, that an operation must take much longer to perform because it is done on a ship or other construction outside a workshop. That is but another rendering of the workshop fallacy that because a bolt is turned in the toolroom, it must take longer than if done in the millwrights' shop or in the production department. It may do, but that may be due to a too ready acceptance of the existence of difficulties, supposed and real.

It is a good thought to keep in mind that there is no difference in the use of tools in or outside a workshop, the difference being

in the conditions obtaining, and it is most desirable that the consideration of these should be made in addition to, but separately from, that of the nominal work. Excepting this be done the ascertainment of the existence of a faulty rate of output will become increasingly difficult, and it can almost be taken for granted that, because of the difficulty of the supervision of ship-fitting, owing to the number of compartments and the unavoidable interruptions caused by through traffic and by other tradesmen working, the rate of output on this work is much lower than the possibilities actually shew, the records of output, which may exist, being even of less value than those of the ordinary workshops.

Chipping is more strictly a matter of area than, say, bedding, because chipping is almost entirely a visual operation, so far as gauging is concerned, whereas, with bedding, gauging is a matter of offering the piece being worked upon to the place in which it is to be fixed, and this is not a matter of area. True, the larger the area the greater the time required because of the weight of the piece, but the two are not proportional.

While it is desirable to have definite data as to the possibilities of output for chipping alone, and also for bedding, it is the best practice, in estimating, to treat chipping and bedding as one operation, including the time for each in the one job rate. The reason for this will be readily appreciated when the dependence of the amount of bedding required, on the efficiency of the chipping, is considered.

The fitting of pads involves the following items:

Remove burrs, scales, bruises, etc., from the surface to be fitted.

Offer pad in position and mark off.

Send to shop for machining.

Chip where required.

Bed, and bolt up for riveting.

Riveting done by riveters.

Remove rivet heads.

Scrape face as required.

While the job rate will be given in terms of minutes per square inch, allowances will be included for each one of these items. It is the better arrangement to treat the work as constituting two separate operations:

1. Fit pad and prepare for riveting.
2. Remove rivet heads and scrape surface.

The first step to be taken is the ascertainment of the time required to perform each detail of the operation for given areas. It will be obvious that a pad of each size and type cannot well be tried, and a good plan is to take four or more typical pads of such sizes that the largest and smallest likely to be handled are included and, also, at least two intermediate sizes. Then from a curve on squared paper, obtained by filling in the respective values and connecting same, read off the intermediate amounts.

If the time required were entirely a question of proportion to area, a factor per square inch could be used more conveniently

TABLE OF AREAS. (No. 32)

Blank and Bored Flanges.

Formula. Area = Sum of radii × difference × $3\frac{1}{7}$.

DIAMETER OF HOLE.

External Diameter.	0	1	1½	2	2½	3	3½	4
1	0.78							
1½	1.77	0.98						
2	3.14	2.36	1.37					
2½	4.91	4.12	3.14	1.77				
3	7.07	6.28	5.30	3.93	2.16			
3½	9.62	8.84	7.85	6.48	4.71	2.55		
4	12.6	11.8	10.8	9.42	7.66	5.50	2.94	
4½	15.9	15.1	14.1	12.8	11.0	8.84	6.28	3.34
5	19.6	18.8	17.9	16.5	14.7	12.6	10.0	7.07
5½	23.8	23.0	22.0	20.6	18.8	16.7	14.1	11.2
6	28.3	27.5	26.5	25.1	23.4	21.2	18.7	15.7
6½	38.2	32.4	31.4	30.0	28.3	26.1	23.6	20.6
7	38.5	37.7	36.7	35.3	33.6	31.4	28.9	25.9
7½	44.2	43.4	42.4	41.0	39.3	37.1	34.6	31.6
8	50.3	49.5	48.5	47.1	45.4	43.2	40.7	37.7
8½	56.7	56.0	55.0	53.6	51.8	49.7	47.1	44.2
9	63.6	62.8	61.8	60.4	58.7	56.5	54.0	51.1
9½	70.9	70.1	69.1	67.7	66.0	63.8	61.3	58.3
10	78.5	77.8	76.8	75.4	73.6	71.5	68.9	66.0
10½	86.6	85.8	84.8	83.4	81.7	79.5	77.0	74.0
11	95.0	94.2	93.3	91.9	90.1	88.0	85.4	82.5
11½	104	103	102	101	99.0	96.8	94.2	91.3
12	113	112	111	110	108	106	103	101
12½	123	122	121	120	118	116	113	110
13	133	132	131	130	128	126	123	120
13½	143	142	141	140	138	136	134	131
14	154	153	152	150	149	147	144	141
14½	165	164	163	162	160	158	156	153
15	177	176	175	174	172	170	167	164
15½	189	188	187	186	184	182	179	176
16	201	200	199	198	196	194	191	188
16½	214	213	212	211	209	207	204	201
17	227	226	225	224	222	220	217	214
17½	241	240	239	237	236	233	231	228
18	254	254	253	251	250	247	245	242
18½	269	268	267	266	264	262	259	256
19	284	283	282	280	279	276	274	271
19½	299	298	297	296	294	292	289	286
20	314	313	312	311	309	307	305	302

External Diameter.	4½	5	5½	6	6½	7	7½	8	8½	9
5	3.73									
5½	7.85	4.12								
6	12.37	8.64	4.52							
6½	17.3	13.5	9 43	4.91						
7	22.6	18.9	14.7	10.2	5.30					
7½	28.3	24.5	20.4	15.9	11.0	5.69				
8	34.4	30.6	26.5	22.0	17.1	11.8	6.09			
8½	40.8	37.1	33.0	28.5	23.6	18.3	12.6	6.48		
9	47.7	44.0	39.9	35.3	30.4	25.1	19.4	13.4	6.87	
9½	55.0	51.2	47.1	42.	37.7	32.4	26.7	20.6	14.1	7.27
10	62.7	58.9	54.8	50.3	45.3	40.1	34.3	28.3	21.8	14.9
10½	70.1	67.0	62.8	58.3	53.4	48.1	42.4	36.3	29.8	23.0
11	79.1	75.4	71.3	66.8	61.9	56.5	50.9	44.8	38.3	31.4
11½	88.0	84.2	80.1	75.6	70.7	65.4	59.7	53 6	47.1	40.3
12	97.2	93.5	89.3	84.8	77.9	74.6	68.9	62.8	56.4	49.5
12½	107	103	99.0	94.4	89.5	84.2	78.5	72.4	66.0	59.1
13	117	113	109	104	99.5	94.2	88.5	82.5	76.0	69.1
13½	127	124	119	115	110	105	99.0	92.9	86.4	79.5
14	138	134	130	126	121	115	110	104	97.2	90.3
14½	149	145	141	137	132	127	121	115	108	102
15	161	157	153	148	144	138	133	126	120	113
15½	173	169	165	160	156	150	145	138	132	125
16	185	181	177	173	168	163	157	151	144	137
16½	198	194	190	186	181	175	170	164	157	150
17	211	207	203	199	194	188	183	177	170	163
17½	225	221	217	212	207	202	196	190	184	177
18	239	235	231	226	221	216	210	204	198	191
18½	253	249	245	241	236	230	225	219	212	205
19	268	264	260	255	250	245	239	233	227	220
19½	283	279	275	270	265	260	254	248	242	235
20	298	295	290	286	281	276	270	264	257	251

External Diameter.	9½	10	10½	11	11½	12	12½	13	13½	14	14½	15	15½	16
10	7.66													
10½	15.7	8.05												
11	24.1	16.5	8.44											
11½	33.0	25.3	17.3	8.84										
12	42.2	34.6	26.5	18.1	9.23									
12½	51.8	44.2	36.1	27.7	18.9	9.62								
13	61.8	54.2	46.1	37.7	28.9	19.6	10.0							
13½	72.3	64.6	56.6	48.0	39.3	30.0	20.4	10.4						
14	83.0	75.4	67.4	58.9	50.1	40.8	31.2	21.2	10.8					
14½	94.2	86.6	78.5	70.1	61.3	52.0	42.4	32.4	22.0	11.2				
15	106	98.2	90.1	81.7	72.8	63.6	54.0	44.0	33.6	22.8	11.6			
15½	118	110	102	93.7	84.8	75.6	66.0	56.0	45.6	34.8	23.6	12.0		
16	130	123	114	105	97.2	88.0	78.3	68.3	57.9	47.1	35.9	24.4	12.4	
16½	143	135	127	119	110	101	91.1	81.1	70.7	59.9	48.7	37.1	25.1	12.8
17	156	148	140	132	123	114	104	94.3	83.8	73.0	61.9	50.3	38.3	26.0
17½	170	162	154	145	137	127	118	108	97.4	86.6	75.4	63.8	51.8	39.5
18	184	176	168	159	151	141	132	122	111	101	89.3	77.8	65.8	53.4
18½	198	190	182	174	165	156	146	136	126	115	104	92.1	80.1	67.7
19	213	205	197	188	180	170	161	151	140	130	118	107	94.8	82.5
19½	228	220	212	204	195	186	176	166	156	145	134	122	110	97.6
20	243	236	227	219	210	201	191	181	171	160	149	137	125	113

than a table; but this is not the case, and largely because the gauging and handling are questions of trial and not of area, as the sizes of pads are increased, so does the time required for gauging, in terms of square inches, become less.

In the building up of tables for fitting it is desirable, as with other tables, that where more than one factor is involved the amount of time occasioned by each should be ascertained and be suitably recorded, so that reference back can be made either for purposes of verification or of modification, as the work or the methods used may be varied. Where this is done the data collected will be rendered more readily available for use in other directions. In this case the items involved are as given below:

Remove burrs. Basis-area.
Mark-off. Basis-size of pad.
Chip. Basis-area and amount of material.
File. Basis-area.
Bed. Basis-area.
Chip rivet heads. Basis-size and number of rivets.
Scrape joint face. Basis-area.

CHIP AND BED PADS—SHIPWORK. (No. 33)

TIME IN MINUTES FOR AREAS AS SHOWN.

AREAS IN SQUARE INCHES.

Hundreds.	0	10	20	30	40	50	60	70	80	90	Per Inch Intermediate Areas
0	—	53	100	145	188	230	271	311	350	388	4.3
1	426	463	500	537	574	610	646	682	717	752	3 6
2	786	819	852	884	916	947	978	1008	1038	1067	3.1
3	1096	1125	1153	1181	1209	1237	1264	1291	1318	1345	2.8
4	1371	1397	1423	1449	1474	1499	1524	1548	1572	1596	2.5
5	1619	1642	1665	1688	1710	1732	1754	1776	1797	1818	2.2
6	1839	1860	1881	2001	2021	2041	2061	2080	2099	2018	2.0
7	2037	2056	2075	2094	2112	2130	2148	2166	2183	2200	1.8
8	2217	2234	2251	2268	2285	2301	2317	2333	2349	2365	1.6
9	2381	2396	2411	2426	2441	2456	2471	2486	2501	2516	1.5
10	2531	2545	2559	2573	2587	2601	2615	2629	2643	2656	1.4
11	2669	2682	2695	2708	2721	2734	2747	2760	2773	2785	1.3
12	2797	2809	2821	2833	2845	2857	2869	2881	2893	2904	1.2
13	2915	2926	2937	2948	2959	2970	2981	2992	3003	3014	1.1
14	3025	3036	3047	3058	3069	3079	3089	3099	3109	3119	1.0
15	3129	3139	3141	3159	3169	3179	3189	3199	3208	3217	1.0
16	3226	3235	3244	3253	3262	3271	3280	3289	3298	3307	.9
17	3316	3325	3334	3343	3352	3361	3370	3379	3387	3395	.9
18	3403	3411	3419	3427	3435	3443	3451	3459	3467	3475	.8
19	3483	3491	3499	3507	3515	3523	3531	3539	3547	3555	.8

For uphand work, ordinary, add 25 %.
" " " difficult, " 50 %.
" radial " " 25 %.
Relative to level of ship 1 way, " 25 %.
" " " " 2 ways " 50 %.

Using the particulars so obtained a table can then be built up from which could be read direct the time required for the fitting of a pad of any given area. A further table from which the areas of flanges of different diameters with varying sized holes could be read at sight would enable the time required for the carrying out of the work involved to be obtained without difficulty. Tables built up on these lines are shewn on pages 359 and 360. Tables for boiler or other steam-tight work will be different from those suitable for ship fitting, owing to the nature of the work.

The foregoing tables are used thus. Let it be assumed that a steel pad is to be fitted, the external diameter and that of the bore being 16 inches and 6 inches respectively. From the table of areas, on the 16 inch line under the 6 inch diameter of hole, the area of the face is found to be 173 square inches. In table No. 33, on the 1 hundred line, under 70 will be read the time required for the bedding of an area of 170 square inches—682 minutes ; on the same line, in the end column, 3.6 minutes per inch are quoted for intermediate areas, and this amount multiplied by 3 to cover the odd inches enables the total time to be ascertained thus :

$$(3.6 \times 3) + 682 = 692.8 \text{ minutes, say } 11\tfrac{1}{2} \text{ hours.}$$

Scraping. Scraping is a hand process whereby small amounts of material are removed with the object of obtaining a better surface than is practicable by the ordinary methods of machining, or to obtain a surface which will bed closely to another, or to a master surface, so that " rock " will be eliminated and, when the surfaces are clamped together, a good rigid joint may be obtained without distortion.

In some cases, scraping is called for, not because the quality of finish from the cutting tool is not good enough, but rather because of the difficulty of clamping, without distortion, the article being machined. Then, while the face left by the tool may be perfectly level, as soon as the clamping bolts are released the amount of distortion set up in clamping, however slight this may be, is shewn up as the metal goes back to its original position. In some other cases, of course, distortion takes place by the removal of the material, and this, by upsetting the existing balance, sets up alternative strains.

For comparatively rough work filing is used, but strictly local application of the file is not readily possible, while the inaccuracies of files themselves render their use unsuitable for the finest work. In many instances where a filed surface is sufficiently good for the purpose, and indeed in some cases where scraping has been resorted to, grinding has been introduced with much success, but its application is not always conveniently possible, and scraping is still a much used process.

The time required for scraping will obviously depend upon the amount of material to be removed and the class of finish required, although the time needed will not necessarily be increased proportionally with the material to be removed. Scraping, like many

other operations, consists really of roughing and finishing, and in estimating the rate of production, more particularly when the amount of material to be removed is a variable quantity, this needs to be borne in mind. Thus, if .003 of an inch were left to be removed by scraping, the removal of the first .002 of an inch would be done in the same time, or less, than the last .001 of an inch, and with less trying against the master surface. The amount of material which can be removed by scraping is sometimes a matter of strength, as in the early stages of an operation, and at others, when the finished surface is being reached, it is a question of skill, the removal of small amounts of material and of frequent trials to make sure that " holes " are avoided.

The appropriate measure for scraping is that of area, and the most convenient unit is that of square inches. The reference may be quoted as square inches per minute or as minutes per square inch. There is no real advantage in one method over the other, but it is thought that the practice of quoting time for work is more logical than to quote work as a basis for time.

It is desirable that some attention should be given as to the amount of material to be left for scraping, either for each job or for each class of work. A common experience is to find that if enough material has been left for removal, parts are passed to the fitters to be worked upon, even if the amount of material left is two or three times as much as is required. This is bad and should be given attention. The laying down of the amounts of material to be left in machining is likely to set up a standard of workmanship for the machine-shop which will have a far-reaching influence. In time-working shops this is especially so.

A standard is more particularly necessary in the case of scraping, because, if job rates are based on the removal of material which is in excess of that really necessary, even though that has been the custom, so soon as a job rate is given the fitter will get in touch with the machinist, and ask him to leave less material to be removed. The fitter will then be paid additional wages, by means of his job rate, because the machinist is doing his work better, meaning possibly higher wages for the expenditure of less energy. In so far as the improvement is the outcome of the workman's own initiative some reward is deserved, but payment by results is not the right medium for payment.

Scraping has many applications. It is required for surfaces where " rock " must be eliminated; for faces when a metal to metal joint is required; for bearings, not only to ensure a finely finished surface but also one that is well-bedded; for slide-valve faces; and sometimes it is called for, purely for the sake of appearance, as in the case of " frosting." In some instances a plain face only is required, while in some others one face may not only have to be well-bedded but also be square with another, or be one of two which, together, must give a specified thickness or be measurable by " clock " from some given position. Each of these conditions

has an influence on the time involved for which appropriate allowances must be made.

Taking the scraping of plain faces first, the time per square inch will be greater for small areas than for large areas, if only for the fact that " marking," to see where the high places are, is needed as many times for a small area, perhaps, as for a large one. This difference, however, is not so great as is sometimes thought. In some shops, for the same class of work, the time allowed has been known to range from 7 minutes per square inch to 1.5 minutes. While varying conditions and requirements will influence the time taken to a considerable degree, it will be rarely found that more than 4 minutes per square inch will be required, and then only for small surfaces of 2 square inches or so. The author has known a steel block to be faced up on 3 sides, the faces truly square with each other, two sides being scraped parallel to gap gauge—42 square inches in 50 minutes, that is three separate faces of 14 square inches each, done in an average time of 17 minutes per side, or say 1.2 minutes per square inch. Large slabs for use as marking off tables have been scraped up at the rate of .8 minutes per square inch.

The difference in the work entailed in scraping plain faces, faces to be square one with the other, and faces which are to be measured for parallelism with each other is approximately as follows :

Plain surface - - - - - - - - -	=100
One surface square with another - - - -	=125
One surface square and at a stated distance or to " gap "	=133.3

The table given overleaf will be found to be a useful guide in this connection, although it may appear, in a workshop where rate of output has been neglected, that the rate suggested will be impossible to obtain. The author has had experiences in this connection as follows :—A table was increased by 50 per cent. in order to induce men to put forth efforts, and was then barely sufficient for the purpose. In another works, even as increased, the tables failed to satisfy the men, while, in another one, they were found to be altogether too high. The range of the table and the size of the steps can be modified or extended as desired.

A point of some interest and importance arises where long narrow faces are concerned. For example, the area of one face of a block 4 inches by 3 inches is 12 square inches ; so is the area of a straight edge 48 inches by .25 of an inch, but it cannot be held that the amount of work involved in scraping a true face up is a matter of area only, and the same in each case. This question is often dismissed as being exceptional and, therefore, as requiring special treatment, but this is only evading the question, and the ordinary man can quite logically ask at what stage does a face become " special."

If mathematical accuracy were reasonably possible, or if it were necessary to recognize in job rates, every minute, a difference in

condition would make, it would be found that the best shaped section for quick scraping was a square one, and that as the difference in width and length grew, the resultant output measured in square inches would be less. Where work of this description occurs a rule of the following kind would apply:

For each time the length of face exceeds 8 times the width add x percentage, say 10 per cent., to the normal estimate. The formula to give effect to this would be

$$\text{straight-edge time} = \text{normal time} + \frac{(\text{normal time} \times \text{length} \times .1)}{\text{width} \times 8}.$$

Then a face 48 inches long $\times$ .25 of an inch wide $=$ 12 square inches, and the estimate would be obtained as follows:

$$\text{Normal time} = 2.3 \times 12 = 27.6 \text{ minutes.}$$

$$\text{Straight-edge time} = 27.6 + \frac{(27.6 \times 48 \times .1)}{.25 \times 8} = 93.8 \text{ minutes.}$$

To meet the different classes of work, either the percentage or the width factor can be modified.

From another standpoint allowance may be necessary. It is unlikely that the precise amount of material will be left to enable a satisfactory surface to be worked up, and when this is several thousandths in excess the amount of work left for the fitter will be considerably increased, although, as stated earlier, not in the same proportion. In such a case, the allowance made should be per thousandth per square inch, and this can be embodied in the scraping table as shewn.

SCRAPING TABLE. (No. 34)

	Minutes per Square Inch.									
Class of Scraping	2.5	5	10	20	30	40	60	80	100	Above 100
Appearance	.6	.58	.56	.54	.53	.52	.51	.5	.5	—
Plain	3.5	2.9	2.3	2.0	1.8	1.6	1.3	1.1	1.0	1.0
Squaring	4.4	3.6	2.9	2.5	2.3	2.0	1.6	1.3	1.2	1.2
Gapping	4.7	3.9	3.0	2.6	2.0	2.1	1.7	1.4	1.3	1.3
Steam-tight	7.0	5.8	4.6	4.0	3.6	3.2	2.6	2.2	2.0	2.0

When more than x thousandths of an inch are left to be removed, allow, as an extra, .25 of a minute per thousandth per square inch.

For gun-metal or cast iron approximately two thirds of the above times are required, although this rule can only be approximate, owing to the fact that the time required for trial or "marking" will be the same for all metals, and therefore should not be reduced. Separate tables are recommended.

The scraping of bearings, while still a matter of area, can conveniently be tabulated under diameters and lengths. The outside surfaces fall under one or other of the heads given in Table No. 34, and require no special reference. Bearings may be bedded in separate halves or in pairs, although the conditions under which

these are fitted and tried in position may vary widely. In some instances, the half bearing may be simply placed on the journal; in others, as with some engine bearings, it may require to be driven into position; while again, as with the bearings for small connecting rods, the two halves may be assembled in the rods themselves, bolted together and marked in that position. Of course, when "marked" in pairs, as in the latter case, some slight economy in time will be experienced as against that required when the marking is done in separate halves. There will be a somewhat greater difference in the times for scraping large and small bearings, material for material, than for the scraping of large and small areas because of the more work involved in "marking"; at the same time less material should be left for removal and, excepting in very large bearings where distortion is difficult to avoid, bedding should not involve the removal of more than a thousandth of an inch. In tabulating data for the purpose, it is advisable to make clear that the table is meant to cover halves or whole bearings, and it is probably the safer plan to make the half, the unit of reference. A table in the following form would be found useful in this connection.

BEARING TABLE—BEDDING. (No. 35)

	Length of Bearing.											
Diameter.	$1\frac{1}{2}$	2	3	4	5	6	7	8	9	10	11	12
1												
$1\frac{1}{2}$												
2												
9												

Tapping. While much tapping is done by machine, there are bound to be some holes which, for various reasons, must be left to be tapped entirely by hand; further, it is quite common that machine taps are purposely made small, the hole to be finished by the full sized plug tap being run through by hand afterwards. So far as the time required for tapping is concerned, it is largely a question of size of tap, class of material and depth of hole, and the accuracy of the job required, although tap guides, where applicable, eliminate the trouble with "square" tapping.

The most trustworthy method of obtaining the necessary data as to the time required for the various sizes, depths, etc., is to have a number of holes, satisfactorily drilled as to size, neither too large nor too small, in varying depths for blind holes, and in different thicknesses for through holes. It is worth while to arrange that both depths and thicknesses shall be greater than those

usually required, so that data can be provided for building up a table which will cover all reasonable possibilities. The taps used should be in good condition; there are really no grounds which justify the using of blunt taps, either as a basis for data or for production, and the tap wrenches should be those generally supplied for use by the workers, although care should be taken that same are in good condition as regards size of square, and that the ends are not so rough as to hurt the hands of the men using them. Then by taking note of the time required for tapping a number of holes of each diameter and depth, making a record also of the time taken in tapping each hole, a suitable table can be built up which can be used as a permanent basis in fixing job rates. It will be found that the time allowed for hand tapping varies in different works to a very large extent. This, in some cases, will reflect the difference in the class of material being worked upon, but this is not always the case.

Under no circumstances is it right to consider the time for tapping a given diameter as being proportional to the depth of hole. Thus, the time required to tap a through hole in material 1 inch thick would not, necessarily, be double the amount required if the material were .5 of an inch thick only; it may be more, it may be less. Tapping increases in difficulty as the depth of the hole exceeds the diameter of the tap, and to fix a time basis at so much per inch is not logical. Not only so, but the tap travel is not increased proportionally with the depth of the thread tapped, excepting in the case of blind holes.

TAPPING TABLE—HAND. (No. 36)
WHITWORTH THREADS—FOR USE ON MILD STEEL.

Size of Tap.	Depth of Hole.							
	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
$\frac{1}{8}$	2·0	3·3	5·0	—	—	—	—	—
$\frac{3}{16}$	1·6	2·5	3·6	5·0	—	—	—	—
$\frac{1}{4}$	1·4	2·0	2·8	4·0	5·5	—	—	—
$\frac{5}{16}$	—	1·6	1·9	2·5	3·0	—	—	—
$\frac{3}{8}$	—	1·5	1·8	2·3	3·0	3·8	5·0	6·5
$\frac{1}{2}$	—	1·5	1·8	2·2	2·9	3·6	4·7	6·0
$\frac{5}{8}$	—	1·5	1·8	2·2	2·9	3·6	4·7	6·0
$\frac{3}{4}$	—	—	2·3	2·7	3·3	4·1	5·2	6·5
$\frac{7}{8}$	—	—	3·0	3·5	4·2	5·1	6·2	7·5
1	—	—	—	4·2	4·9	5·9	7·2	8·7

Allow $\frac{2}{3}$ of above times for brass and cast iron.
For rough work deduct 10 %.
For awkward tapping allow according to difficulties.

Where blind holes are concerned tapping is not so readily done. A common practice is to allow a definite amount per hole tapped to cover this. As a rough and ready rule this is not seriously wrong,

but the influence of the hole being blind is reduced as the depth exceeds the diameter, and accordingly as the hole is drilled deeper than the depth of tapping required.

On the previous page is given a table which has been used for tapping holes in steel, a good class job being required.

Fitting Keys and Keyways. The fitting of keys and keyways is often handled throughout on the basis of area. While area is really the true basis, yet so many different rates per square inch are required that lineal inches per size and length or depth form a more satisfactory reference. For example, on the area basis a keyway for a .5 inch key would be given approximately double the time which would be allowed for a .25 inch key. This would be incorrect, because the gauging or trying in position would be approximately the same in each case, while the actual fitting time itself would not be proportional to the area. Further, two keyways of the same width but of different lengths would not take proportionally the same time; if one were 1 inch long and the other were 2 inches long, the longer keyway would not require double the time of the shorter one, 50 per cent. to 66.6 per cent. extra would be sufficient according to the nature of the finish required and the influence of diameter of hole on the work; the smaller the hole the greater does the difficulty of fitting become, and this difficulty is increased as the hole is deepened.

In most works, standard dimensions are used for keys and keyways according to the diameters of the shafts. In those cases, tables can be built up on the basis of shaft or hole diameter, for one or more keys, to suit the various requirements. These are most diverse but, for a really good fit, keyways in open holes up to 4 inches diameter require for the first inch from 7½ to 11 minutes; additional lengths can be dealt with as suggested. Where the quantities are large enough to justify the manufacture of broaches, the need for fitting would be eliminated.

Plate Work. With some classes of work, as aeroplane manufacture, fittings are called for to be made in steel plate, and, because of the comparatively small quantities required when the aeroplanes ordered are few in number, the provision of press tools is not always justified, and the somewhat costly method of making by hand has to be adopted. It is when the use of costly methods is unavoidable that economy is most needed, when estimates should be most nearly correct, and to ensure this a tabulated list of estimates can be of great assistance.

The preparation of plates ready for bending, obviously bending times cannot be tabulated because of the different finished forms, consists of the following operations:

Cut from sheet.
Mark off.
Cut to shape.
Level.
File to shape.

The cutting from sheet should be done under a guillotine and should be kept quite distinct from the bench operation. In the majority of cases no marking-off should be necessary, position stops being used for cutting off. The operation is a short one and should not exceed a few seconds.

Dependent upon the quantity, marking-off and cutting-out will be done with or without the aid of filing jigs. If without filing jigs, the first one can be marked off, cut out and filed up and be used as a template for marking-off the remainder, thus saving time. If a filing jig be provided, this can be used as a template, and after the pieces are cut they can often be filed several at a time, particularly when the material is of a thin gauge. In some cases the filing jig can be used also as a drilling jig, and this makes it convenient for, say, two holes to be drilled in the plates, two pins being inserted through jig and plates serving to locate the plates on the jig for filing.

Tables as shewn on the next page are useful in this connection.

When nibbling machines are used, similar tables to those for cutting can be built up.

Marking-off or lining-out, as it is sometimes called, has been quite commonly treated as presenting too many difficulties for the estimating of rate of output or for the application of payment by results. Like all other forms of hand labour, individual skill and energy have marked influence, but even as the work to be done can definitely be described so can it be subjected to some degree of measurement.

It is desirable, too, from several points of view, that marking-off should be dealt with similarly to other classes of work. If payment by results be introduced into a fitting shop, then, although it is common for a marker-off to be paid a higher rate than fitters, because of the importance of the work, such differences would soon be counterbalanced by the extra pay which the fitters would be able to earn and dissatisfaction would be likely to follow, ending in an application for additional wages. If increased wages were given, without any reference to output, increased cost of work would probably follow.

From another direction, consideration is necessary. If as a result of the operation of payment by results in the machine and fitting shops a bigger volume of work is turned out per hour, it follows that more marking-off will be necessary, and, excepting a similar increase in the amount of marking-off done, is obtained, more markers-off and more slabs for their use will be required: incidentally more space. Both points are of importance, and need to be given careful consideration if efficient costs are to be possible.

Actually marking-off offers no undue difficulties in estimating. Marking-off consists chiefly of the making of measurements, the delineation of centres, circles, straight lines, etc., on rough castings, forgings, and partly finished pieces for the guidance of machinists and fitters in setting and working upon same. Marking-off may be described as drawing on metal, copying only from the drawing being

PLATE WORK. (No. 37)

Steel Plate. Cut Out by Hand. Straight Cutting.

Thickness. m/m.	Thickness. Fractional.	Length of Cut. 1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.039	.3	.5	.7	.9	1.1	1.3	1.5	1.7	1.9	2.1	2.5	2.9	3.3	3.7	4.1
1½	.059	.37	.61	.86	1.1	1.3	1.6	1.8	2.1	2.3	2.6	3.1	3.5	4.0	4.5	5.0
2	.079	.43	.72	1.0	1.3	1.6	1.9	2.2	2.5	2.7	3.0	3.6	4.2	4.8	5.3	5.9
2½	.098	.5	.83	1.2	1.5	1.8	2.2	2.5	2.8	3.2	3.5	4.2	4.8	5.5	6.2	6.8
3	.118	.57	.94	1.3	1.7	2.1	2.5	2.8	3.2	3.6	4.0	4.7	5.5	6.2	7.0	7.7
3½	.138	.63	1.1	1.5	1.9	2.3	2.7	3.2	3.6	4.0	4.4	5.3	6.1	7.0	7.8	8.7

Curved Cutting.

Thickness. m/m	Thickness. Fractional.	Length of Cut. 1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.039	.4	.72	1.0	1.4	1.7	2.0	2.3	2.6	3.0	3.3	3.9	4.6	5.2	5.8	6.5
1½	.059	.49	.88	1.3	1.7	2.1	2.4	2.8	3.2	3.6	4.0	4.8	5.6	6.4	7.1	7.9
2	.079	.58	1.0	1.5	2.0	2.4	2.9	3.4	3.8	4.3	4.7	5.7	6.6	7.5	8.4	9.4
2½	.098	.67	1.2	1.7	2.3	2.8	3.3	3.9	4.4	4.9	5.5	6.5	7.6	8.7	9.7	10.8
3	.118	.76	1.4	2.0	2.6	3.2	3.8	4.4	5.0	5.6	6.2	7.4	8.6	9.8	11.0	12.2
3½	.138	.84	1.5	2.2	2.9	3.5	4.2	4.9	5.6	6.2	6.9	8.3	9.6	11.0	12.3	13.7

Above 10″ radius treat as straight. For brass allow ⅔ of above times.

PLATE WORK. (No. 38)

Steel Plate. File to Shape. Straight.

Thickness. m/m.	Thickness. Fractional.	Length of Profile. 1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.039	.50	.83	1.2	1.5	1.8	2.2	2.5	2.8	3.2	3.5	4.2	4.8	5.5	6.2	6.8
1½	.059	.65	1.1	1.5	2.0	2.4	2.8	3.3	3.7	4.1	4.6	5.4	6.3	7.2	8.0	8.9
2	.079	.80	1.3	1.9	2.4	2.9	3.5	4.0	4.5	5.1	5.6	6.7	7.7	8.8	9.9	10.9
2½	.098	.95	1.6	2.2	2.9	3.5	4.1	4.8	5.4	6.0	6.7	7.9	9.2	10.5	11.7	13.0
3	.118	1.2	1.9	2.7	3.5	4.2	5.0	5.8	6.5	7.3	8.1	9.6	11.1	12.7	14.2	15.7
3½	.138	1.3	2.2	3.0	3.9	4.8	5.6	6.5	7.4	8.2	9.1	10.8	12.6	14.3	16.0	17.8
4	.157	1.5	2.4	3.4	4.4	5.3	6.3	7.3	8.2	9.2	10.2	12.1	14.0	16.0	17.9	19.8
5	.197	1.8	2.9	4.1	5.3	6.4	7.6	8.8	9.9	11.1	12.3	14.6	16.9	19.3	21.6	23.9
6	.236	2.1	3.4	4.9	6.2	7.5	8.9	10.3	11.6	13.0	14.4	17.1	19.8	22.6	25.3	28.0

Curved Work.

Thickness. m/m.	Thickness. Fractional.	Length of Profile. 1	2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.039	.83	1.5	2.2	2.8	3.5	4.2	4.8	5.5	6.2	6.8	8.2	9.5	10.8	12.2	13.5
1½	.059	1.0	1.8	2.6	3.4	4.2	5.0	5.8	6.6	7.4	8.2	9.8	11.4	13.0	14.6	16.2
2	.079	1.2	2.1	3.0	4.0	4.9	5.8	6.8	7.7	8.6	9.6	11.4	13.3	15.2	17.0	18.9
2½	.098	1.3	2.4	3.5	4.5	5.6	6.7	7.7	8.8	9.8	10.9	13.1	15.2	17.3	19.5	21.6
3	.118	1.5	2.7	3.9	5.1	6.3	7.5	8.7	9.9	11.1	12.3	14.7	17.1	19.5	21.9	24.3
3½	.138	1.7	3.0	4.3	5.7	7.0	8.3	9.7	11.0	12.3	13.7	16.3	19.0	21.7	24.3	27.0
4	.157	2.0	3.6	5.2	6.8	8.4	10.0	11.6	13.2	14.8	16.4	19.6	22.8	26.0	29.2	32.4
5	.197	2.3	4.2	6.1	7.9	9.8	11.7	13.5	15.4	17.3	19.1	22.9	26.6	30.3	34.1	37.8
6	.236	2.6	4.8	7.0	9.0	11.2	13.4	15.4	17.6	19.8	22.8	26.2	30.4	34.7	39.0	43.2

Thin plates should be filed two or more together, the time allowed to be on the basis of the combined thickness.

Allow ⅔ for brass. Allow .1 minute for each vice setting.

required. In doing so it may be necessary for the marker-off to check all dimensions, to make sure the casting or forging may "clean up," and quite often he is able, where there is a discrepancy or a "leanness," to save the piece by "throwing" the lines over.

Marking-off then consists of work which can be defined and detailed, and its time value, therefore, can be estimated. The operation, analyzed, is made up of lifting and setting the piece to be marked-off, finding the position, marking same off, and "popping," so that the disappearance of the chalk or other marking used to shew up the lines will not mean losing the position.

Lifting the job into position is similar to the lifting of jobs on to machines or elsewhere. The time required will vary from .05 of a minute in the case of small vee block or plain slab work to 40 minutes in the case of cylinders and other large castings.

The actual marking-off must sometimes be divided into preparation and marking-off. The picking up of the centre of a shaft is done but once, whether 1 or 100 pieces have to marked-off, and once picked up the actual striking of the centre line is a very small operation; it is the same with the setting of dividers and surface gauges. Then where the quantities to be handled are likely to vary, it is advisable to make a batch allowance for items of this kind, leaving the job rate per piece to cover those items which must be repeated per piece done.

The finding of a centre in a light shaft or spindle will take about 1.5 minutes, but the actual marking-off, dependent upon the length, will take, say, .1 of a minute. In the same way, the setting of surface gauges takes longer than their use, and once the positions have been found, and the different gauges set, the actual marking-off is often purely a mechanical operation. This is at once an argument for the provision of a sufficient number of surface and other gauges to enable the marking-off of individual pieces to be done without the re-setting of any tool.

With these points kept in view and a practical man to handle the work, the estimating of rate of output for marking-off becomes a fairly simple matter. Data can be tabulated on the following lines:

MARKING-OFF DATA. (No. 39)

Setting.	*Minutes.*
Light spindle in vee blocks	.1
,, ,, ,, set square	.5
,, machined faces set square	.5
,, forgings or castings, square and level	3.0
Rough or heavy castings, etc.	5 to 40
Lifting on and off slab	.1 to 15
Straight Lines.	
Find centre of light spindle	1.5
Mark off short centre lines	.1
Add for long ,, ,, per foot	.1
Vertical lines—short	.15
Add for long lines per foot	.1

Circles.	*Diameters of Holes.*				
	1″	2″	4″	6″	12″
Scribe circle and pop, per hole	.5	.66	.83	1.0	1.5

Mark off position for holes on pitch circle and pop - - - .15

Setting Tools.	*Minutes.*
Surface gauge, small	.5
,, ,, large	1.
Dividers	.5
Rule on angle bracket in definite position	1.5

From data of this kind can be built up inclusive estimated times for jobs which recur, such as the marking-off of flanges for drilling; of square holes for slotting; of keyways and keybeds, etc., etc.

Assembly and Erection work is similar to that of fitting. According to the efficiency of the design and the excellence of machining, assembly will either justify its description or become an operation of rectification and adjustment as well as of assembly. Of course, some adjustment in assembly must be expected, particularly on large and heavy work, but, as organization and inspection are unsatisfactory, so will assembly costs be higher and variable. This is the experience in light as well as heavy engineering and is the cause of the waste of much valuable time and money.

In these circumstances, it is sometimes quite impossible to estimate, at once, the time the whole of an assembly operation will be likely to take because the amount of work entailed cannot be foreseen; a progressive estimate is then the only solution. By a progressive estimate is meant the addition of time to an estimate, as the amount of work involved can be specified, the assembler being given additions to his job rate as the work is proceeded with.

An assembly estimate, as with fitting and other estimates, is built up by allowing the requisite time for each detail. For those adjustments which are obviously unavoidable, time must be allowed; if these involve chipping, scraping and so on, the tables for fitting will apply; those which are peculiar to the product can be allowed for on a basis which can be built up. Where parts are held together by bolts it is a question of so much time per bolt according to the size; the assembly of pinions, pulley bushes and the like is similarly treated. If gear teeth require adjusting the basis should be so much per tooth, although the area of the tooth is a basic factor. These are all of a nature which are affected by the class of work, and, in each works, standards must be built up which are suitable to the special requirements.

CHAPTER XXXII

PRODUCTION ESTIMATING—TOOL-ROOM WORK

PARTLY because the quantities called for in connection with tool-room work are usually small in number, and also because of the natural difficulties of the work, rate of output in tool-rooms is often a neglected quantity. The assumption is often made that payment by results cannot be applied with any real prospect of a satisfactory return because of these factors, and the somewhat common experience is that tool-room output is much less than it should reasonably be. It would be wrong to suggest that to estimate the rate of output possible for this class of work can be done as easily as is the case with production work of a standard character ; it cannot : it is not so straightforward, there are so many variables, while the difference in the degrees of skill available go to make correct estimating more difficult. It needs to be remembered, however, that while there may be difficulties in estimating rate of output in this connection, yet, for the purposes of supervision and control, an adequate idea of the possibilities is necessary, otherwise effective supervision is difficult, and it is this fact which is one of the chief causes of low tool-room output.

Because of the high standard of efficiency required with much of the work done in tool-rooms, some managers fear the quality of the work would suffer if any inducement were offered toward quick output. This aspect of the question has been dealt with in Chapter III. The standard of work required is laid down by the management of a works, and its attainment depends upon the existence of the requisite skill and, in turn, this reflects, in a considerable degree, the endeavours made to reach that standard. In any case, the expenditure of much time is not the solution, and many firms who make payments in accordance with results for the work done in their tool-rooms have derived much benefit therefrom, even where the work done was of the most accurate class.

There is a considerable amount of glamour cast over what is known as tool-room work, the reaction of which has been bad as well as costly. Some firms adopt a most unwise policy of putting any work which requires a fair measure of accuracy into the tool-room, the inference being that the men employed on the ordinary work of

production have not, nor can be expected to have, the requisite skill. This is quite a mistake. There are tool-rooms where the standard of workmanship called for is lower than that required for some production shops. If the work done in many tool-rooms were examined and classified, it would be found, possibly, that the larger portion of it was of a comparatively simple nature which did not call for more skill than that possessed by the average worker—not tool-maker.

It is not desired to belittle the skill required in tool-making, but it is to be recommended that tool-making shall be separated from the simple apprentice work which is so often given the name. Some of the work done calls for skill and intelligence of the highest order, and truly efficient men are neither numerous nor easily found.

Cases of the following kind are too common. Three firms were engaged in the same class of manufacture. Two articles in constant demand were produced in one works, in their production shop, in half the time taken in the other two works where the work was treated as tool-room work ; the rates of wages paid were lower also. In one of the works if a turner, in the production shop, were given a plain bolt to turn, which had to be fitted to a machine, he would demand the " tool-room rate." The mistake lies in allowing genuine tool work to be mixed up with that of a nondescript character.

Tool-room work differs from other classes in the standard of accuracy required rather than in the processes used ; these are precisely the same as elsewhere, and it follows that the methods of estimating are similar also. Roughing for tool work is no different to that called for on production work ; sometimes it is desirable in the interests of accuracy to use less heavy cuts in order to avoid straining machines, but these are matters of detail and discretion, which can be provided for in the tables laid down, or, better still, by arranging for the roughing to be done on machines where the maintenance of accuracy is not a matter of importance. Unduly heavy cuts, of course, may set up strains in the material, which may lead to distortion at the time or at a later stage in the manufacture of the tool. The care and skill is called for, really, in the obtainment of the class of finish specified and this, of necessity, is a highly varying matter.

As a matter of fact, with some of the finer classes of work, the time required in its performance is a matter more of blind knowledge than of demonstrable detailed facts, and, as with some other types of work, there is a wide field for research which is worth attention. There is but little doubt that one of the reasons for low output in tool-rooms is the lack of knowledge as to what are the real time factors. That the chief factor is that of additional handling in the form of gauging is certain, and if the correct relation of this to the removal of material in the various processes were established a great step forward would be made.

In spite of the drawbacks under which much of the work has to be done, as will become obvious as the possibilities are examined,

and although tool-room jobs are often different in detail, it is surprising to find how much repetition there actually is and to what extent the different jobs are measurable by common rules. If this were not so the cost of estimating would be a heavy one, although not necessarily so heavy as to render its doing unprofitable. Many of the standard tools, such as plug and ring gauges, both plain and screwed, taps, milling cutters, reamers and the like, will, probably, be purchased outside, although it does not follow that this is always the cheaper course. While in works where they are manufactured for the market repetition methods are possible, yet, handled in accordance with the possibilities rather than with tool-room traditions, it is often found that some of these can be profitably made in the works, even in small quantities. In the case of special tools and gauges of this kind the supplier's price is often prohibitive, while the question of delivery is likely to be an important factor.

Confining attention to the manufacture of special tools, in small quantities, it will be found possible to estimate and to tabulate the estimates, so that much of the work can be handled with the same ease as can the standard work of a production department. Thus, where the manufacture of plain or formed milling cutters is concerned, although each one may be different in dimensions and in the number and the pitch of the teeth, yet, up to a stage, they are plain steel collars or bushes and may be treated as such. In the cases where a special form is required, time for the machining of this can be added, the complete estimate being arrived at as a result of further estimating, or, as is possible with certain classes of "forms," as with radii, from further tabulation.

PLAIN MILLING CUTTERS. (No. 40)

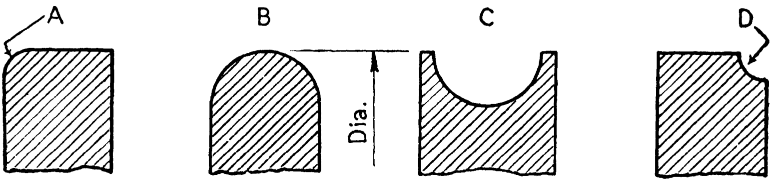
BORE AND TURN COMPLETE

Diameter.	Length in Inches.																
	½	¾	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3½	4	4½	5	5½	6
2	33	37	41	44	48	52	56	60	65	69	73	81	89	98	107	114	122
2¼	35	39	43	47	50	54	58	62	67	71	75	84	92	100	109	117	126
2½	37	41	45	49	53	56	61	65	70	74	78	87	95	104	112	121	130
2¾	39	43	47	51	55	59	64	67	72	76	81	90	98	107	116	124	133
3	42	46	50	54	58	61	66	70	75	79	84	93	102	111	119	128	137
3½	47	52	56	60	64	68	73	77	82	86	91	101	110	119	128	137	146
4	53	57	62	66	70	74	80	84	89	93	98	108	117	127	136	146	155
4½	61	65	69	74	78	82	88	92	98	102	107	117	127	137	147	156	166
5	68	72	77	82	86	91	96	101	106	111	116	126	137	147	157	166	177
5½	76	80	85	90	94	99	105	109	115	120	125	136	146	156	167	177	187
6	85	90	95	99	104	109	115	120	125	130	136	147	157	168	179	189	190

An example of this is to be seen in the turning of cutters for milling radii. Cutters are frequently required to mill radii both convex and concave, and the time for the turning of these can be tabulated against the different sizes and types under the diameters of the cutters on which the radii are required. The possibility of the extension of this practice to other forms, although forms are

mostly radial, will be obvious. A convenient method of tabulating these estimates is shown below.

MILLING CUTTERS.—RADIUSED. (No. 41)
ESTIMATES FOR TURNING RADII.



Size and Type of Radius.		Diameter of Cutter.										
Size.	Type.	2	2¼	2½	2¾	3	3½	4	4½	5	5½	6
.1	A B C D											
2.0	A B C D											

To obtain the complete times for turning radiused cutters, add above times to those for turning plain milling cutters, Table No. 40. When more than one radius of above types is called for, these times must be increased accordingly.

The milling of the teeth can be similarly treated, and a sample table for this is given on page 291, in the chapter on milling. Tables can be built up for the turning of reamers, finger mills, centres for lathes and milling machines, etc., etc. In the case of finger mills, where the size of the material used may be controlled either by the size of the taper of the machine spindle or the diameter of the cutter, tables can be built up to give the times for turning the various tapers in use from the different diameters of material likely to be used, leaving the turning of the cutting portion of the cutter to be estimated or taken from another table for that purpose. Collaboration with the tool designer, however, would tend to reduce these variations to a minimum.

Jig Boring. The boring of jigs can be conveniently handled as regards the time involved although, where the lathe is used for this purpose, jig boring is one of those operations referred to earlier in the chapter, where the correct relation of cutting and handling time needs to be established. Jig boring, where great accuracy is concerned, consists of the boring of a number of holes of a diameter smaller than that finally required, accurate gauging of the position of the holes by the use of slip and plug gauges taking place for each diameter of hole bored, adjustment to the position being made as found required. When suitable attachments are used, with graduated movements, much of this work of trial is eliminated. Consideration of the work needs to be split into boring and gauging. The initial setting can be taken separately, but in the gauging of jig holes, because of its nature, the changes to the setting of the job must be included, the need for this being disclosed by the gauging done. Excepting on jig boring machines, where the holes bored are less than 1 inch in diameter and depth, the cutting time is not an important feature.

A common practice is to allow for the boring of small holes on the basis of the gauging called for rather than of size. Thus, if holes are required to be bored in a position correct from one point, the setting and gauging is much simpler than as though accuracy in two directions is called for. For example, if in each of two rectangular plate jigs one hole is called for and, in one case, the centre is required to be 1 inch from one side only, and in the other is called to be 1 inch from each of two sides, the gauging difficulties are at least doubled. The times required per hole, under the different conditions, vary somewhat as follows :

Holes Bored.	Without Special Attachment.	With Special Attachment.
Correct from 1 point -	1 hour	$\frac{1}{4}$ to $\frac{1}{2}$ hour
,, ,, 2 points -	1 ,, 40 min.	20 min. to 40 min.
On pitch circle - -	1 ,, 40 ,,	20 ,, 40 ,,

In order to cover the initial setting and the starting up of the job, it is a good plan to arrange the time allowed per hole on a net basis ; otherwise if the initial setting time be spread over the time per hole, then for the boring of a jig with one hole the time allowed would be too small, while the allowance for another jig with, say, six holes would be too great. The better method is to allow x time per hole according to the class of job plus an overall time. Thus, if 3 holes had to be bored the estimated time could be 1 hole at 1 hour, 2 holes at $1\frac{1}{2}$ hours each plus $\frac{1}{2}$ hour to cover initial setting—a total of $4\frac{1}{2}$ hours.

The difference between the time required as a result of the different grades of accuracy called for, can be provided for by graduating the time per hole accordingly. Thus a hole correct from a given position with a tolerance of .001 of an inch would require more

time than as though the tolerance were .002 of an inch, and so on. The times for the boring of holes can be tabulated in this manner.

Taps and Screw Gauges. The turning of taps and screw gauges differs from ordinary work only in the accuracy required. This varies accordingly as the National Physical Laboratory Certificate or an equivalent standard is called for, or whether a lower standard is acceptable. The threads called for in some classes of production work are more accurately finished than are some screw gauges.

As with other items of this kind, there should be a general standard observed so that estimates can be tabulated, and thus save time by the avoidance of re-estimating. Where the size of gauge required is sufficiently different from the standard to warrant an estimate, this detail only would need to be dealt with.

With screw gauges and taps the special item is always the thread, but in many cases estimates can be taken out and tabulated for the whole work involved, so that when any repetition takes place the looking up of the estimated time takes but a matter of seconds.

Once the standard of accuracy required is known, factors for cutting the various threads can be arranged so that the difficulties of estimating will be largely overcome. This standard, varying so much as it does, makes it impossible for any figures of value to be given. Screw plug gauges, 1 inch in diameter, have been turned and screwed in 1½ hours, while in other instances as many as 6 hours have been taken; similar variations in time occur with screw ring gauges.

Taps as a manufacturing proposition are handled in a much different manner than when done in tool-rooms—a matter of some significance; but, while the question of the class of finish still applies, odd sets of taps can be turned and screwed in from 1 hour to 1½ hours per tap for .25 inch taps and 2½ hours to 3½ hours for 1 inch taps.

If it be arranged to give a sketch of the gauges or the taps, as the case may be, letters instead of sizes being quoted on same, a table can be built up to give the respective dimensions and also the operation and times.

Tool Fitting. To a great extent much of the tool-fitting done is of a similar character to that of ordinary high-class machine fitting. The fitting of jigs and fixings is of this character, and the tapping, scraping, etc., can all be dealt with by the same methods of estimating. It will be dependent upon the degree of accuracy required as to the amount by which the ordinary allowances for fitting in the production shops need to be increased. Where great accuracy is called for, grinding should be resorted to wherever possible. This is done with such gauges as key-plug gauges, gauges for square and hexagon holes, and this, because of the possibility of removing material in the hardened state, has led to better gauges, longer life, and cheaper production.

The skill in tool-making is not required so much in the bedding

of faces, however accurate these may need to be, as in the development of figures for which no pattern or model exists, a typical example of which is the making of plate gauges.

Plate Gauge Making. There are many types of plate gauges, the requirements for which are exceedingly varied; and while the considerations are always profile, length of profile alone does not give a true indication of the work to be done. In some instances, such a rate as 1 hour per lineal inch of profile has been used, while in others attempts have been made to use area as a basis. The latter appears to have no logical application whatsoever; area, as such, could enter into the question only when the thickness of the gauge exceeded, say, .25 of an inch.

In many instances, the really difficult work in the making of a plate gauge never appears, the development of the "checks" representing the most difficult portion of the work, as with tooth gauges; with the checks once made, the production of the gauge proper becomes a comparatively simple matter. As against this, in the making of a radius gauge, the necessary checks are usually readily available in the shape of plug gauges or reamed holes.

To estimate efficiently for plate gauge-making, considerations other than length or square inches of profile must be made, and this is best done by estimating each section of the work separately, including checks when required.

The first operation is to prepare the plate in a rectangular form, cut out and level, and dress the edge; this part of the work is often treated as a separate operation. The time required will be affected by the thickness and the area of the plate. In some works, the edges and surfaces are ground so that the gauge-maker's time is confined to the more important part of the work. It is convenient to build up a table giving the estimated times either for given sizes, or it may be of more universal value for specified areas.

According to the practice of the works, the table can be extended to cover the grinding of the edges and of the surfaces as desired.

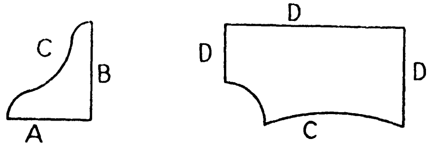
The next step is to mark off the form of the gauge. The thickness of the material does not affect the time required for marking-off, it is rather the number of points and lines and their relative positions. Marking-off is of more importance with gauges than with ordinary production work, and seeing gauges are usually made in quite small quantities, generally one off only, the times for marking-off can, as a rule, be made to include the setting of the various tools used. Lengths of line, the sizes of diameter or radii can, generally, be ignored in marking-off gauges owing to the fact that they do not vary within wide limits. The exceptional cases can be dealt with as they arise. In the sample table on page 379 a method of dealing with this item is shewn.

The fitting of the profile face of the gauge is the most important in gauge-making and the most difficult to estimate. Analyzed, it can be said that short lengths of profile take less time to "get up" than long ones, and straight lines than curved lines, but short lengths

take more time per inch of profile than do the greater lengths; therein lies the fallacy of a standard time per inch.

Plate gauges are either "nibbled out" or drilled and cut with hack saw to avoid distorting the material, but in either case the time required is one of lineal inches, plus an allowance for obtaining drills and preparing the machine. The next step is to get the profile up, and this is matter of lineal inches plus gauging or trying with the check.

GAUGES PLATE. (No. 43)



Area Sq. in.	1	2	4	8	16	32
Cut out Sq. Form and Face.	8	10	12	15	20	30
Length. of Profile.	Drill and Cut Out Figure.	FIT.				
		A	B	C	D	
½	3	10	12	60	6	
1	2.5	7	9·3	50	4	
1½	2.3	6	8	45	3·5	
2	2.2	5	6.7	42	3·0	
3	2.1	4	5·3	38	2.5	
4	2.0	3·2	4·3	36	2.0	
6	1.9	2.5	3·2	34	1.5	
8	1.8	2.0	2.6	33	1.2	
10	1.7	1·7	2.3	32	.8	
12	1.6	1.5	2.0	30	·7	

Time for cutting out to square form is given per job.
,, ,, fitting, per lineal inch per job.
Line out—straight lines—parallel = 2 min.
,, ,, ,, ,, angular = 3 ,,
,, ,, radial ,, = 2 ,,
Each line of profile to be treated independently.

So far as the compilation of any reliable data is concerned, the subject is not only a difficult one, because of the variability of the requirements, but all too little attention has been given to the

matter, and the fixing of job rates for plate gauge work to-day is largely a matter of trial, "experience," and the time previously taken. In some instances it is known that tolerably good results have been obtained, and that some of the tables built up are, from this standpoint, satisfactory, but they are records which have no detailed evidence and no arguable basis.

The variation is exceedingly wide. Thus gauges filed to lines, only, can be made at the rate of, say, 3 minutes per inch of profile, while a pair of tooth gauges with not more than 1 inch of profile, including the necessary checks, will take 10 to 12 hours. The precise manner, however, in which the time is taken with the latter is not known, nor can the men who actually make the gauges go further than to say it is a matter of filing and gauging.

It may be thought by some that the ascertainment of the detailed facts is not worth while. While it is obvious no one firm is able to undertake all the investigation necessary, to work in the dark is not good at any time, and that is the position as regards the rate of output possible on much of the work done of this description.

CHAPTER XXXIII

PRODUCTION ESTIMATING—INSPECTION

THE inspection of work at intermediate stages of manufacture, as well as when completed, is being recognized as essential and as being more in the nature of an economy than an expense. The need for inspection, independently of the system of payment in use, has been dealt with elsewhere (see Chapter III.) as also have the risks attending the use of an individual or even a collective system in connection with inspection (see Chapter IV.).

With reference to the latter, it was pointed out that under certain conditions the objection referred to disappeared, and that an individual system could be applied to inspection without undue risks being taken. Where these conditions apply, or where the risks referred to appear to be negligible and an individual system of payment by results is adopted, the methods by which rate of output can be estimated must be considered.

The fixing of job rates for inspection is really one of the simplest in connection with engineering manufacture, although it is necessary for the term and the function to be defined. In many cases, the inspector not only inspects, but he also carries out minor adjustments, and in this connection, even where the inspectors are working under the time system, grave abuses are to be found.

In one works, where the piece-work system was in use, inspectors were paid under the time system. The finished productions were sent to the inspection department in a state known to be unfinished, the erector obtaining a larger percentage of extra pay in consequence. Extra men were required in the inspection department to cope with work which was not inspection but adjustment, due to the unfinished state of the work sent in. Later the inspectors were paid by results; adjustment by inspectors was not allowed; the erectors' extra pay was not paid until the work had been finally passed. Piece-work earnings were affected in consequence, as also was the number of inspectors required, but an all-round saving was shewn, and a better standard of work was induced.

Intermediate inspection presents a problem of its own in this respect, and, because of the mass of detail handled, requires careful consideration as to whether payment by results can be efficiently

applied or not. It would be unwise to say it is impossible; it could be equally unwise to recommend it. At the same time, whether it be adopted or not, the data used for fixing job rates would be identical with that used in connection with the inspection of the completed work.

If a machine or instrument is to be taken apart, so that each detail can be inspected, the first step is to allow for the dismantling precisely as this has to be done. This will consist of slackening and removing screws, bolts or nuts, a time for each of which is necessary. For example, small nuts can be removed in from .1 to .2 of a minute each, screws likewise. Where a large number of small screws are concerned, Archimedean screw-drivers should be used, but whatever the nature of the work or the methods adopted, the splitting of operations into their respective details must be a first consideration.

Where a number of assembled pieces of mechanism are concerned and dismantling is necessary, if possible, these should all be dismantled first, then inspected, and afterwards re-assembled. The different items should not be handled separately if this can be avoided.

The dismantling done, inspection of the parts becomes necessary. Where standard gauges are concerned, as plug, ring and slip gauges, no alternative methods need be considered, and the time required for their use is readily standardized. Thus the use of plain plug gauges, on small repetition work, takes .05 of a minute or even less, while the use of the same gauge on isolated holes can be as much as .2 of a minute. In the first place, the pieces should be laid out, for which time must be allowed, so that the gauge need be picked up but once and can be tried in all the holes with a minimum of handling; with isolated pieces each gauge and piece has to be handled separately. The same applies to screw gauges, gap or caliper gauges, length gauges and the like.

The use of the micrometer often offers a problem to the estimator. It is rarely that a firm supplies sufficient micrometers, or even adjustable caliper gauges, to their inspectors to enable each one to have enough of these to run over a batch of parts without resetting being required. That being so, the estimator has no option but to allow time for setting the micrometer for each reading. In such a case the enterprising inspector, or probably several, by investing in two or three micrometers are able to beat the estimator and recoup themselves for their expenditure.

Because of the influence of quantities on output, where inspection is concerned, great care is required, and it is necessary in estimating to keep gauge setting quite apart from the actual work of inspection.

Length, of course, must be considered. Thus a shaft 6 feet long may have but one diameter, but the diameter gauge, whether it be caliper or ring, must be applied more than once, or must pass over the whole length; it follows, therefore, that length and also diameter will have an influence on the time taken.

One of the best examples of this is the screw-ring gauge.

A 1.5 inch diameter screw, 6 threads per inch, 2 inches long, could be inspected in .5 of a minute, but a similar screw 30 inches long would not take proportionally longer. On the other hand, if the pitch of the thread were 12 to the inch the time would be increased in proportion. To build up estimates or factors for the different lengths, pitches and diameters, it is necessary to consider the operation as having 4 elements, and the time for each could be as shewn:

	Minutes
Visually inspect for appearance - - - - - -	.10
Pick up gauge, put into position and put down - -	.10
Pass gauge over thread - - - - - - - - -	.33
Return gauge - - - - - - - - - -	.16
Total time - - - - - - - - - -	.69

The distance actually to be covered in the gauging of screws is the length of the screw plus the thickness of gauge and, on the assumption that a gauge is 1 inch thick, the gauging of a screw 2 inches long would entail the passing of the gauge over a distance of 3 inches. As per example given, this would be for gauging and return, .11 and .055 minutes per inch respectively. When many parts had to be inspected and the gauge could be passed right over, no return being necessary, modification to job rates may be necessary. The time required to gauge a thread 30 inches long similar to the above would be as follows:

	Minutes
Visual inspection for appearance - - - - - -	.2
Pick up gauge, put into position and put down - -	.1
Pass gauge over .111 × 31 - - - - - - -	3.44
Return ,, ,, .055 × 31 - - - - - - -	1.71
Total time - - - - - - - - - -	5.45

The requirements of the work of course affect gauging of this kind considerably. Where it is needed for threads to be cut so small that the gauge can be passed over freely, the time per inch may be as low as .05 of a minute. A table as indicated overleaf will enable the estimated times to be quickly read off, although where standard Whitworth threads only are cut, the table could be built up to suit.

A similar table would be useful in connection with the use of screw plug gauges.

Where plain shafts are to be inspected, it is necessary to fix the basis similarly. If ring gauges are used, the time required to use same will be increased as the lengths and diameters of the jobs being inspected are increased. If caliper gauges or micrometers are used it is necessary to allow for a stated number of gaugings according to length of shaft, and the time for the inspection of any shaft will be either for the use of the gauge once, multiplied by the number

of gaugings required, or be a stated time per foot based on the latter.

There follows then the necessity to fix the time required for the use of each type of gauge. These must be arranged to suit the require-

EXTERNAL SCREW THREADS. (GAUGING No. 44)

Threads per Inch.	Minutes per Inch for Various Diameters.							
	·5	1	2	3	4	5	6	8
20								
18								
:								
4								
Add per screw gauged								

ments of the individual works, but a tabulation of the following kind is necessary, one aim being to keep the time for the setting of the gauges, where such is necessary, from that for the use of same:

INSPECTION DATA. GENERAL. (No. 45)

Type of Gauge.	Considerations of Job which affect Gauging Time.	Minimum Time in Minutes.
Plug, plain -	depth and diameter of hole - -	.05
Ring, ,, -	length ,, ,, ,, shaft - -	.1
Plug, screwed	depth, pitch and diameter of thread	.15
Ring ,, -	length ,, ,, ,, screw	.2
Caliper - -	,, ,, ,, ,, - -	.05
Slip - -	,, - - - - - - -	.05
Length - -	,, - - - - - - -	.1
Rule - -	,, - - - - - - -	.05
Surface - -	size and height - - - -	.15
Square - -	,, - - - - - - -	.15
Protractor -	,, - - - - - - -	.15
Depth - -	,, - - - - - - -	.1
Profile gauge -	length of profile - - - -	.1
Micrometer -	set only—size of micrometer - -	.25
Vernier - -	,, ,, vernier - - -	·3
Surface - -	,, ,, and height of gauge -	.25

For a particular class of work, say, where the pieces to be inspected are large in size and the quantities are comparatively small, it will be found convenient to allow complete times for the gauging and handling of the pieces, but a table so based could not be used for another class of work, at any rate, until the conditions had been reviewed and the suitability of the table had been confirmed. With repetition work, handling can be reduced to a minimum, and in some works, where both repetition and jobbing work are handled, this factor is not given the attention necessary, and output suffers in consequence. Some years ago an estimator was sent from one works to another to deal with the question of inspection as regards output. He had been used to the inspection of jobbing work of rather a large size, and was somewhat surprised to find that, on the time system, the amount of work being done was considerably in excess of that to which he had been used under payment by results, in some instances on similar classes of work.

In inspection, it will generally be found that there are some pieces which are spoilt in manufacture, and that others, while not correct to gauge, are not spoilt and can be rectified. In either case it is necessary that particulars of the fault shall be written down for the information of the chief inspector and of the foreman responsible and, where rectifiable work is concerned, for the information of the department by whom the necessary adjustments are to be carried out. Time must be allowed for the writing out of such reports, either so much per report or as a percentage of the estimated time to be included in the job rate. The latter is probably the better arrangement.

Where intermediate inspection is paid by results, payment should be made for the number of pieces inspected, independently of whether all the pieces are passed or not. If this is not done, the inducement will be to pass faulty pieces rather than reject them, because, by rejection, the extra pay would be reduced.

A most important point to be observed with inspection, and indeed with manufacture, is the need for definite instructions as to the standard of workmanship and size tolerances which are to be accepted. This matter is often neglected, and the production and the inspection departments are frequently left to use their own discretion as to what is required, and this, because of the varying opinions held, results sometimes in disputes and bad feeling.

The application of a measure of output to the work of inspection is worthy of consideration where the time system is in use. Possibly next to tool-rooms and the millwrighting departments, inspection departments afford the most fruitful sources of investigation. In some works inspection is treated as an unavoidable evil, and if payment by results is in use, as one of the penalties which must be paid for its use. This attitude is quite a wrong one. Inspection properly carried out can justify its cost, and in some cases the subsequent results have proved inspection to be a real economy. True economy, however, is difficult to secure without a measure of output by the use of which the work done can be valued.

CHAPTER XXXIV

MISCELLANEOUS WORK

In most works there will be found a number of processes which do not fall under any of the main heads. Amongst these may be mentioned engraving, welding, painting and varnishing, aeroplane covering, turbine blading, broaching, sawing and many others too numerous to mention. It would be a difficult matter to cover all processes, but a few will be dealt with which will indicate the possibilities and will go to emphasize the need all the time for analysis. Any and every new process should be approached from this standpoint, and should there be a big gap between the results obtained and those foreshadowed as possible as a result of the analysis, the latter should more often be found the safer guide.

Sawing—Machine. There are three types of metal toothed saws in common use, the band, the circular, and the hack-saw. For ordinary work the use of one or other or the three is more a matter of possession than of any special suitability. Possibly the band-saw is the most universally useful. As regards the estimating of the rate of output, the cutting time can be estimated by the use of the following formula:

$$\text{cutting time} = \frac{\text{length of travel}}{\text{feed}}.$$

The length of travel with the band and hack-saws is the same as the dimension of the job, that is, 3 inch bar requires 3 inches travel, although in the latter case this is strictly true only where round bars are concerned ; with square or flat work the position in which the saw works not being parallel with the basis of the vice necessitates a deeper traverse than that of the actual dimension of the job. Because of the nature of the feed, however, there is a tendency to counteract this. With the circular saw the length of travel is slightly greater than the length of the job because of the radius of the saw.

Circular Saw. In the case of the circular saw the operation is practically the same as milling, and the most satisfactory method of ascertaining the rate of production possible is to make suitable tests of the feed per minute which can be obtained on the various

classes of material, either all sizes or at stages, plotting the results on squared paper for the purpose of obtaining the times for intermediate sizes. In this connection it is wise either to plot feeds per minute independently of the setting of the bars or to plot both. By plotting feed per minute, irregularity, due perhaps to belt slip, is more likely to be disclosed.

Band-sawing. With the band-saw, while the feed of the machine is mechanical, and therefore definite, the strength of the saw itself to withstand the cuts is a matter requiring consideration, and the area of cut is the factor which controls output. It is necessary to ascertain by test what the cutting capacity in square inches is, (1) with a sharp saw, (2) with a saw when it requires re-sharpening, then from observation as to the number of square inches cut off, (3) with a saw half way between these two conditions.

Tests so made—more than one test in each condition is necessary—will not only enable a reliable basis to be built up for estimating, but will provide useful data as to when it pays to continue work with a saw and when to re-sharpen. It is quite commonly accepted if, say, the cutting capacity of a tool is 100 when newly sharpened and 50 only when sharpening is again required, that the mean of 75 represents an average that is fair. The probability is that the deterioration of the condition of the saw takes place at a much more rapid rate as it requires re-sharpening than at an earlier stage. In such circumstances the mean taken would be on the generous side, while if the opposite were the case the resultant estimates would be low.

The cutting capacity of band-saws depends, of course, upon the class of material being cut, but possibly more so upon their own thickness and condition because of their comparative frailty. In mild steel, this capacity varies from .4 to 1.25 minute per square inch.

A table, as shewn on page 388, will be useful, but where different classes of material are to be cut, this could be extended to include the estimates for these by separating the setting and cutting times and quoting the former in a separate column.

Hack-sawing. The time required for hack-sawing is even more dependent upon the condition of the saw than is band-sawing, and where payment by results is in use for hack-saw work, it is advisable to keep the issue of new saws under careful control; if this is not done extra pay can be earned not so much by keeping machines running as by the prodigal use of saws. As with band-saws, tests are required with saws in different conditions. It is worth while noting and recording the performance of saws per piece cut off, from the time the saw is first used until it is deemed unfit for further use.

From such a set of observations the time average can be obtained, and if an occasional check be taken over a week's work of the square inches cut and the number of saws used, a waste of saws can be guarded against. On the basis of the law of averages the earnings

of the sawyer could be taken as an indication of the position. If the life of a saw were taken to be 100 square inches and the average rate of cutting were 3 minutes per square inch, then, assuming that 16.6 of the total time is spent in setting or otherwise than in sawing, there would be approximately 39 hours available for sawing, out of a total of 47 hours. This at three minutes per square inch would mean that 780 square inches should have been cut off in that time, and that not more than 8 saws should have been used in so doing.

BAND-SAWING TABLE. (No. 46)

MATERIAL—M.S.

Dimensions.	Round.	Square.	Area.
1	1.7	2.0	1.00
1¼	2.3	2.6	1.56
1½	2.9	3.4	2.25
1¾	3.7	4.3	3.06
2	4.4	5.3	4.00
2¼	5.2	6.2	5.06
2½	6.2	7.4	6.25
2¾	7.2	8.6	7.56
3	8.3	10.0	9.00
3½	10.8	13.2	12.25
4	13.4	16.8	16.00
4½	16.7	21.2	20.25
5	20.4	25.5	25.00
5½	24.3	30.5	30.25
6	28.7	36.0	36.00
6½	33.3	41.8	42.25
7	38.4	48.0	49.00
7½	43.8	54.0	56.25
8	49.3	61.0	64.00
8½	54.7	69.0	72.25
9	60.0	77.0	81.00
9½	68.0	85.0	90.25
10	75.0	94.0	100.00

For rectangular material allow time, in accordance with the area, from "square" column.

Then, if the output were above that estimated, and this was accompanied by an increase in the number of saws used, the value of same could be deducted from the extra pay earned. On the other hand, where a large number of hack-saw machines are used, a payment of one half the value of the saws saved, on the basis of the standard laid down, would be worth considering. Tabulation is a simple matter, and can be conveniently arranged for different materials under the headings of round, square and rectangular forms.

In passing, it might be mentioned that, while with the use of hack-saws the area cut is a useful basis, one flat factor based on area alone is not really correct. As an indication of this, particulars of several tests made in the order as stated below, using the same saw and class of material, will be of interest :

Size of Material.	Area of Cut. Square Inches.	Saw Cutting On.	Time Taken.	Minutes per Square Inch.
$\frac{1}{2}''-1\frac{1}{2}''$	$\frac{3}{4}$	$\frac{1}{2}''$ thickness	2 min. 21 sec.	2.9
$\frac{3}{8}''-2''$	$\frac{3}{4}$	2″width	3 ,, 46 ,,	4.6
$\frac{3}{8}''-2''$	$\frac{3}{4}$	$\frac{3}{8}''$thickness	2 ,, 35 ,,	2.9
$\frac{3}{8}''-2''$	$\frac{3}{4}$	2″width	3 ,, 49 ,,	4.7
$\frac{3}{8}''-2''$	$\frac{3}{4}$	2″ ,,	3 ,, 26 ,,	4.4

This goes to suggest that, from the standpoint of time taken, the amount of work done increases as the length of surface cut is reduced. The effect on the life of the saw, however, is a matter which should be noted.

Engraving. A considerable amount of machine engraving of letters and figures is done to-day, particularly where instrument work is concerned. Estimates are usually based on data collected as a result of observation. A preliminary to the making of observations should be the ascertainment of the most suitable cutting angle for the tool used, and for the material being cut. In some works this is of special importance, because too little attention is given to the efficiency of what is often a small and comparatively unimportant department. Efficiency in this regard being obtained, observations can be made of the time for cutting different letters and figures in the varying sizes used.

The operation consists mainly of three items :

1. Set job on machine.
2. Engrave.
3. Shift from figure to figure.

With setting in engraving, as with other processes, this must be dealt with for individual jobs ; oft-times it must be left entirely to the discretion of the estimator.

Engraving time is quoted for letters or figures without differentiating either. As a rule the law of averages applies. In a special case allowance can be made. Thus the figure 1 could be allowed a special time as shewn in the table given for purposes of illustration on page 390.

Sometimes, graduations are required, and it is best to allow for these as such. They are sometimes engraved in the same way as figures and letters, and sometimes are cut with a non-revolving tool. The

latter is the quicker method, but is apt to leave a nasty burr the removal of which can counterbalance the saving otherwise made.

The time for engraving letters and figures varies from 5 seconds for the small sizes to 20 seconds for the larger, and for graduations according to length. A table of the following kind is required :

ENGRAVING TABLE. (No. 47)

Engrave.	Size.	.1	.15	.2	.25	.3	.4	.5	.6	.7
Letters and Figures.	Time in Secs.	7	8	9	10	12	14	16	18	20
Graduations.		4	4	4½	5	5½	6	6½	7	7½

Dots. 3 seconds. Fig. 1 as graduations.
Shift from figure to figure. 4 seconds.

Broaching. Broaching is a comparatively new process, for which, with repetition work, there is a big future. Although used more generally in the finishing of holes of irregular shape, broaching has been applied to round holes with considerable success. The operation is a simple one and is made up of three items, setting, cutting and return. Setting is of the simplest character, the action of cutting keeping the pieces, which are usually "floating," in position.

The cutting speed is slow, being as low as 3 feet per minute for mild steel. The return speed provided is much faster. The time spent in return is not necessarily idle time, it being possible to remove the piece broached and to have the next one in position while the broach head is being returned. For this reason it is advisable to treat the cutting and return as separate details of the operation, so that the setting or the handling of pieces will be allowed for only as required.

The formula for estimating the time required is as follows :

$$\text{Cutting time} = \frac{\text{length of travel} \times \text{number of broaches}}{\text{cutting speed}}.$$

Length of travel should be stated in inches and covers the length of broach plus the length of the hole being broached. The cutting speed should be given in inches. The return speed being known, the same formula can be used or the cutting time can be divided by the appropriate factor.

Welding. Welding, whether done by the electrical or oxy-acetylene process, is measurable as to work done in lineal inches and in accordance with the gauge of material used. The operation really consists of two sections, "tacking," fixing the pieces to be welded by spot welding at suitable intervals, and the ordinary actual operation of welding.

The amount of tacking required depends upon the nature and the weight of the pieces being welded, and it is desirable that, for specified conditions as with pipes, circles, etc., the number of tacks to be allowed for should be tabulated together with the amount of time per tack, and where possible the time for setting the pieces in position as well.

It will be found that more time per inch is required for short lengths of welding than for long runs. Thus a pipe made of 16 gauge material, 64 inches long can be welded in 9½ minutes or at the rate of .15 minutes per inch. Such an allowance for a job with but one or two inches of welding would be of little use. The best plan is to tabulate times for repetition work and for jobbing work, to specify times for tacking and welding, separately, for definite lengths, together with the conditions which are presumed to obtain.

Thus, taking a small and intricate class of work as welding aeroplane fittings, a table of the following kind would be useful.

WELDING SMALL FITTINGS. (No. 48).

	Gauge	22	20	18	16	14	12	10	8
Per Inch	Straight	.5	.53	.56	.59	.62	.66	.7	.75
	Curved—Tubes	.75	.8	.78	.90	.93	1.00	1.05	1.125

Allow .25 minute per tack, .5 minute per unwelded piece handled.

Painting, Varnishing, etc. The time for painting, varnishing and whitewashing, and for similar operations, is obviously one of area and the number of coats required. Among some of the factors which need to be considered are the nature of the material being used, as to whether it is " stiff "or otherwise; the size of the brush which can be used; for example, window frame work, although a matter of area, can be more conveniently measured in lineal inches; the position in which the work has to be done, as standing on the floor, ladder or scaffold, and whether overhead or not. The various factors known and their relative influence, tables can be built up to give the time per square foot or square yard per coat, or per job as required.

In those cases where preparation takes a considerable time or where the work is difficult to get to, as on the top of a workshop, for the whitewashing of roof-lights, or in the erection of a scaffold, the tabulated time should be kept independent entirely of that required for " handling " or travelling. Of course, once a job has been done and a repetition involves the same amount of work, the estimate previously taken out should have been recorded and used again.

Where spraying machines are used for this class of work, the area basis would still be the one on which output would be measured.

The varnishing of the woodwork of aeroplane fuselages, planes, etc., is chiefly a question of lineal inches, while the doping of the fabric is a matter of area and number of coats.

Aeroplane Work. The time required for the covering of aeroplanes can be conveniently estimated. Where the material is cut out separately for each piece, the time required for cutting is best allowed for per lineal foot of seam to be sewn plus a handling amount based on the approximate area to be covered. Tacking, to keep the cover in position, should be allowed for per lineal foot of seam, and in some cases this can be arranged to cover sewing as well. "Stringing" is best allowed for per knot, also the marking-off and cutting of eyelet holes, and punching the eyelets in the same manner. Patches should be allowed for on the same basis.

More than one rate per foot may be necessary for sewing, according to its nature, and this, of course, should be per lineal foot.

Possibly the aeroplane industry, as much as any in existence, exemplifies the evil effects of faulty production control. In its infancy, aeroplane manufacture was controlled, largely, by men whose knowledge was of flying rather than production and the bad effects of this are yet to be seen in the deplorably low outputs of some aeroplane works to-day. Consequently, a considerable amount of investigation is desirable before any system of payment by results is introduced in an aeroplane works, in order to guard against the stabilization of costs on the basis of low rates of output, or the need, later, of cutting job rates, in order to make it possible to meet competition.

Airship Work. A large portion of airship work is of an ordinary engineering character and requires no special reference. Because of the large amount of repetition work in the building of the hull, or framework, it is advisable that the data used in the estimates of production should be adequately examined before being put into use, otherwise their tendency may be to restrict output, because of their liberality.

The making of the balloons or gas-bags is of a similar character to the fabric work of aeroplanes. Seam work is a matter of time per lineal yard including rubber solutioning; varnishing is a matter of area. It is convenient to give job rates for separate panels, and then, for the assembly of these, further rates for the joining of the circumferential and end panels, still further operations and job rates being required for the assembly of the ends to the circumference and for the necessary finishing-off.

The work of lining with gold-beater's skins is, perhaps, less well known than most of the other operations. This work, however, consists chiefly of two operations, the cleaning of the skins and the laying of same. After the skins have been washed, they require scraping to remove the particles of fat which may be left on. For this work time should be allowed per skin, the amount required being about 1 minute each. After this operation they are ready for laying on the fabric and this is best allowed for on an area basis, approximately 3 hours per square metre being required.

Another operation worthy of mention, because of its influence upon the total weight is that of the varnishing of the gas-bags. It

was found, in one case, that the weight of the individual bags, was greater than the specification permitted and investigation made it clear that this was due to the varnish being laid on too thickly. This may appear to be an exaggeration but when the huge bag area is considered as well as the need to avoid undue weight, the possibilities will be appreciated.

The reason was at once attributed to the influence of payment by results, the desire of the workers to make large earnings being held to have encouraged "scamping." There may have been a measure of truth in this but no special instructions had been issued as to the need to watch this point—in fact the influence of varnish on the weight was a new discovery. Thin coats being necessary, the payment was arranged so that thin coats, quickly put on, would be the result.

The estimates were based on the area of the individual bags. Each bag was weighed before being varnished. The examination was a two-fold one, namely, visual examination to ensure that every portion of the surface had been efficiently covered, and a weight test, to ascertain the weight of the varnish put on. Normal amount of extra pay was ensured when the weight was within 5 per cent. of the mean. This amount was increased as the weight was greater or less than this mean, no payment being due when the maximum weight allowed was exceeded. Thus if the weight were 5 per cent. less than the mean, the extra pay was increased by 10 per cent. When the mean was exceeded, the reductions were so arranged that the whole of the extra pay which may have been earned, otherwise, would be cancelled when the maximum was passed. By this arrangement, the inducement all the time was not only for quick work but, even more so, was for good work, which thus presents a very good case against the suggestion that good work and payment by results cannot go together. The probability is that, with payment arranged in this manner, better as well as quicker work can be assured than under the time system.

Millwrighting. It is not an uncommon feature to find that millwrighting is done on a time basis even in a works where payment by results is general on production work. When the requirements are examined, however, it will become apparent that the difficulties of measuring the time value of the work to be done are more apparent than real and that, as with tool-room work, much of it can be satisfactorily estimated and further, that, in many instances, tabulation is possible.

This is obviously so, as far as machine work is concerned, the conditions being not unlike those which obtain with work of a jobbing character. As an indication of the possibilities of tabulation, the truing up of commutators, for electric motors, by turning, can be quoted. A repair of this kind is usually urgently required and the turning necessary is often done before a job rate could be estimated, excepting the rate-fixer were waiting to prepare same. The work involved, usually, is that of straightening the shaft, scraping the

centres, to ensure true running, and of turning the commutator. The work of turning is affected by the diameter and length of the commutator, while the larger the diameter, the heavier the armature and the more difficult the handling. These items, however, are more or less of a standard character and times can be estimated and tabulated for the various sizes. Such a table is given below.

COMMUTATORS—TURNING—REPAIRS. (No. 49)

OPERATION—STRAIGHTEN AND TURN.

Dia.	Length in Inches.										Setting Allowance.
	1	2	3	4	5	6	7	8	9	10	
2	17	19	21	23	—	—	—	—	—	—	10
3	18	21	24	27	30	33	—	—	—	—	10
4	21	25	29	33	37	41	45	49	—	—	10
6	27	33	39	45	51	57	63	70	77	—	15
8	—	40	47	54	61	68	75	82	89	96	20
10	—	—	58	67	76	85	94	103	112	121	25
12	—	—	—	80	91	102	113	124	135	146	30

Other repairs of a recurring character can be dealt with on similar lines. Among these may be mentioned such work as the making of bushes; the re-bushing of pulleys; the turning of square thread screws such as are used in the tool-rests of lathes and "independent" chucks; the turning of odd bolts can be taken from Table No. 18 on page 312.

The hand-work of a millwrighting department can be similarly treated. With new work, no great difficulties appear and, as with the fixing of machines, standard times can be estimated for the different sizes and types, as lathes, milling machines, etc., or for the details, as countershafts, pulleys, etc., in accordance with the conditions obtaining. Examples of these are as follows:

Fix 6″ lathe with single speed countershaft and striking gear - - - - - - - - - - 8 hours

Fix 6″ lathe with two speed countershaft and double striking gear - - - - - - - - - $9\frac{1}{2}$ „

Fix 12″ lathe with single speed countershaft and striking gear - - - - - - - - - - 10 „

Fix 12″ lathe with two speed countershaft and double striking gear - - - - - - - - - $11\frac{1}{2}$ „

Milling machines, grinders, and the like, can be similarly dealt with as also can the following: The fixing and changing of pulleys, the erection of hangers, brackets, etc., and other work incidental to shafting, recurring repairs to machines, etc., etc.

In some instances when a repair is required, it is not possible to see, at once, what work has to be done; dismantling is necessary

before the extent of the repair can be ascertained. In such cases progressive estimates must be given as indicated on page 371, under assembly work.

Belt Repair. This is usually a neglected and an inefficiently conducted section. Some discrimination is necessary when considering whether to do this under payment by results or not, but, where delays are experienced in this direction, considerable improvements can be effected. Working always from the beltman's headquarters the time required covers the journey to the job and back and the carrying out of the repair. A written slip is advisable, on which are given the machine number, particulars of the repair required, width of belt, time and date. This serves as a check against imaginary repairs and also gives useful information as to the frequency of repairs. The alternative to payment by results, because of the difficulty of supervision, is to employ more men than really necessary and even then delay is often experienced.

Smithy Work. In the majority of cases the time for smithy work is arrived at by the application of experience. Comparatively little attention has been given to the investigation of the relative values of the time for heating and working, and inconsistent job rates are features of much smithy work. Where steam and drop hammers are used, real economies are oft-times possible by the provision of better heating facilities. New hammers and extra fires or furnaces are often provided, when more fires only and some re-organization were necessary.

To deal efficiently with smithy work, it is necessary to ascertain the time for heating different lengths and sizes of material in various sections, both for " first " heats and also for subsequent heats. The time for which heat can be retained to allow the material to be worked efficiently should also be ascertained. These particulars being known, the number of heats required to work material of a given size and section to those of other sections will provide a sound basis for the estimating of rates of production and job rates. Tables can also be built up which would obviate the need for further estimating and these would be useful in the planning of operations when the alternative of bar material or forgings was being considered.

In many smithies the practice is to pay by weight rather than by numbers of articles done. This may be convenient and, where customers are willing to buy by weight, not unprofitable but, from the point of view of efficient and truly profitable workmanship, and economy of material, especially where the firm uses its own forgings, payment by quantity is decidedly better. Where drop forgings are concerned, the dies used controlling the size and, therefore, the weight, payment on a weight basis has fewer objections.

For drop forging work, tables can be built up as with other processes. The principal factors are the weight of hammer, the size and shape of the rough material, and the number of heats

required. This latter will depend upon the amount of displacement of material and also upon the weight of hammer used. Some discrimination is necessary in this respect. A comparatively light job, because of the displacement of material, may require an extra heat when done under a light hammer ; this goes to point out the necessity to consider displacement as well as weight when allocating jobs to hammers. While separate job rates may be required when different hammers are used, it cannot be taken that this must always be the case. Quicker work will be obtained only when the additional hammer weight enables a heat to be dispensed with. In some works, this factor is not considered and reduced job rates are given when the additional weight is a drawback rather than an advantage.

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CHAPTER XXXV

USEFUL FACTORS

In dealing with the various matters which arise in connection with the estimating of rates of production and costs, it is necessary, at times, to be able, quickly, to convert expressions from one form to another. While to do so may not be difficult, yet, because, perhaps, of the amount of calculation required or because those involved are not done sufficiently often to be familiar, the time taken in their doing is more than can be spared or is available and the need for short cuts is felt even though approximate results, only, are obtained thereby. Quite often, such short cuts are useful when superficial checks are being made or when " snap " estimates are necessary; sometimes access or reference to records is difficult and the approximate cutting speed or number of revolutions is needed. Below are given particulars of a few short cuts which may, at such times, prove useful.

Increased Output and Reduced Time Taken as Percentages of Each Other. Sometimes, when the time taken on a job has been reduced, it is desired to give the result in terms of a percentage increase in output or, *vice versa*, when the quantity done in a given time has been increased, the results may be required in terms of a percentage reduction in time taken. Due to the lack of a simple formula, such calculations often take longer than is really necessary. To obtain the percentage of either an increase or a reduction in output or time taken requires no explanation but formulae are given which will enable the results to be obtained in the terms required. For the application of these, outputs of 100 and 125 articles in 100 hours, and times taken of 100 hours and 80 hours, respectively, for an output of 100 articles, will be considered.

When quantities are quoted and the hours taken are the same,

$$\text{percentage increased output} = \frac{\text{difference in numbers done} \times 100}{\text{original number done}}.$$

Thus with the increased output indicated,

$$\text{percentage increased output} = \frac{(125 - 100) \times 100}{100} = 25\%.$$

For the percentage reduction of time taken per piece, when figures are quoted as above,

$$\text{percentage reduction in time taken} = \frac{\text{difference in numbers done} \times 100}{\text{new numbers done}}.$$

Using the same figures,

$$\text{percentage reduction in time taken} = \frac{(125 - 100) \times 100}{125} = 20\%.$$

When hours taken are quoted and the quantities are the same,

$$\text{percentage increased output} = \frac{\text{difference in hours} \times 100}{\text{new hours taken}}$$

$$\text{then percentage increased output} = \frac{(100 - 80) \times 100}{80} = 25\%.$$

The formula for obtaining the percentage of reduction in time taken is, of course,

$$\frac{\text{difference in hours} \times 100}{\text{hours formerly taken}}.$$

If the percentage of reduction in time taken per piece be required when quantities are quoted for the same hours, the formula is as follows:

$$\text{percentage of time taken} = \frac{\text{old number done} \times 100}{\text{new number done}}$$

and for the figures used,

$$\text{percentage of hours taken} = \frac{100 \times 100}{125} = 80\%.$$

Cutting Speed. When it is not convenient or possible to refer to cutting speed tables or, as is sometimes the case, when the references, therein, do not cover the diameters or the revolutions required, it is an advantage to be able to calculate, readily, either the diameter, the revolutions, or the cutting speed, two of these being known. The slide rule, probably, provides the most accurate and ready means of calculating these, but for those who are not users of slide rules, approximately correct figures can be obtained by the use of the following formulae.

The circumference of a 1 inch circle is .261799 of a foot; if .26 be used, the error will be less than 1 per cent. while if .25 be used the error will be approximately 4.5 per cent. each being low. Using the latter figure as being the most convenient for mental work, the items mentioned below can be readily obtained.

$$\text{Revolutions} = \frac{\text{cutting speed}}{\text{diameter} \times .25}.$$

$$\text{Cutting speed} = \text{diameter} \times \text{revolutions} \times .25.$$

$$\text{Diameter} = \frac{\text{cutting speed}}{\text{revolutions} \times .25}$$

Thus, for a mental calculation, the revolutions required to give a cutting speed of 60 feet per minute on an 8 inch diameter would be obtained by dividing 60 by a quarter of 8. The revolutions thus obtained would be 30. The correct number is 28.6. Similarly, if the revolutions were known, say 64 per minute, and the diameter were 5 inches, the cutting speed would be obtained by multiplying one quarter of 64 by 5, 80 feet being the result. Further, if it were desired to know what diameter would enable a cutting or a peripheral speed of 100 feet per minute to be obtained when the revolutions were 80 per minute, then 100 divided by a quarter of 80 would give the diameter as 5 inches; the correct figure would be 4.77 inches.

When these results are not sufficiently accurate, the error in using .25 instead of .261799 can be overcome by the addition or subtraction of 5 per cent. or $\frac{1}{20}$ accordingly as .25 is used as a multiplier or a divisor. Thus in the last instance, .25 is a divisor and the resultant answer, consequently, is high. 5 per cent. subtracted from 5 inches leaves the more correct figure of 4.75 inches. The 30 revolutions arrived at by formula, would become 28.5 as against the accurate number of 28.6, while the addition of 5 per cent. to 80 gives 84 feet as against 83.7 feet, the correct amount.

For the ascertainment of the revolutions required to give one definite cutting speed, as, say, 60 feet per minute, the number of revolutions required to give 1 inch diameter this speed can be used as a factor, the same to be divided by the diameter of the piece in inches, for which the revolutions are required. Thus 229 revolutions per minute being required to give a diameter of 1 inch a cutting speed of 60 feet per minute, the number of revolutions necessary to give the same cutting speed to a diameter of 4 inches would be $\frac{229}{4} - 57$ revolutions. For .5 inch diameter, the revolutions required would be $\frac{229}{\cdot 5} - 458$.

Estimating. Rough Guides. It is often an advantage in dealing with estimating, to be able to make a kind of superficial check or to be able to arrive at an approximate figure, without going through the routine of examining or working out each detailed calculation. Thus, in the case of the machining of flat faces, a time or money factor per square foot can be worked up for known classes of work, which will be accurate within a small percentage. In a similar manner, the machining of blanks for spur and bevel pinions, wormwheels, flanges, etc., can be approximately estimated, on the basis of diameter. It is necessary, however, to provide a second factor to cover setting, handling, and gauging. As intimated in Chapter XXIV., when dealing with the tabulation of data, the time required for the performance of work is rarely strictly proportional to area or to the amount of material removed only. There is always the varying difference between the handling of the various kinds,

and the removal of material, and this fact must be borne in mind when arranging rough guides for estimating purposes. Setting should always be allowed for separately.

With planing, the factor would take this form :

20 minutes or 4 pence per foot, plus
30 minutes or 6 pence per piece done.

With lathe work, the factor would be x amount per inch of diameter. Some bevel pinions can be turned at the rate of 20 to 30 minutes per inch of diameter. Taking the latter figure, the factor would be used thus:

30 minutes or 6 pence per inch of diameter, plus
30 minutes or 6 pence per piece done.

Spur pinions may be done in about 20 minutes per inch, while the allowance for wormwheels may need to be 40 minutes per inch of diameter. These will depend of course upon the design, separate rates being required to suit the design peculiar to a particular works. In addition to these, suitable allowances per piece done would be necessary.

Gear-cutting can be treated somewhat similarly although the length of face, even more than the pitch, requires consideration when the rates are arranged on a diameter basis. A price per inch of tooth could be arranged on the basis of Table No. 11, page 93. All the tables used in a works could, if desired, be given values in money, for estimating purposes, but, whether this be done or not, it will be apparent that many rough guides of the kind described, can be profitably built up for use in the different classes of manufacture.

Conversion of Job Rates. Job Rates to Cost Hours. In connection with estimating it is required, sometimes, to know quickly the cost of work when the rate of production is other than that estimated. It may not be necessary to know the amount of extra pay earned or, in fact, the time taken. Such calculations however take time and, when done by people not used to same, can prove to be a source of trouble.

In the case of the Halsey-Weir system it is possible to ascertain the cost hours of a job by use of the following formula :

$$\text{Cost hours} = \frac{\text{job rate} + \text{time taken}}{2}.$$

For example, if the job rate were 100 hours and the time taken were 58 hours then

$$\text{Cost hours} = \frac{(100 + 58)}{2} = 79 \text{ hours}.$$

Similar short cuts cannot be taken with the Rowan or the Halsey $33\frac{1}{3}\%$ systems, while with the Taylor system the working out is so simple that short cuts are unnecessary ; with the Plain Premium 100% system, there is no reduction in cost and, therefore, no

calculation is involved until the guaranteed time rate operates. Factors prove useful, however, where it is desired to know either, the cost of production, when a given percentage of the job rate is saved, or the relation of the actual cost to the estimated cost, when more or less than the estimated time has been taken. While these are more generally required for rates of output which are between, say 20 per cent. above or below estimate, factors are given covering the saving of from 10 to 90 per cent. of the job rates appropriate to the various systems. Tables of this kind will be found useful for purposes of reference.

TABLE OF FACTORS. (No. 50)

To Indicate Hours Paid.

For Different Percentages of Time Taken and time Saved

Percentage Job Rate.		Halsey-Weir.			Rowan.		
Taken.	Saved.	Percentage Extra Pay.	Factor.	Percentage of Estimated Cost.	Percentage Extra Pay.	Factor.	Percentage of Estimated Cost.
100	Nil.	Nil.	1.00	125	Nil.	1.00	113
90	10	5.5	.95	119	10	.99	111
80	20	12.5	.9	113	20	.96	108
75	25	16.6	.875	109	25	.9375	105
70	30	21.4	.85	106	30	.91	102
66.6	33.3	25.0	.83	104	33.3	.888	100
60	40	33.3	.8	100	40	.84	94.5
50	50	50	.75	93.8	50	.75	84.4
40	60	75	.7	87.5	60	.64	72.0
33.3	66.6	100	.66	83.3	66.6	.555	62.5
30	70	116.6	.65	81.3	70	.51	57.4
25	75	150	.625	78.1	75	.4375	49.2
20	80	200	.6	75.0	80	.36	40.5
16.6	83.3	250	.583	72.9	83.3	.3055	34.4
12.5	87.5	350	.5625	70.3	87.5	.2344	26.4
10	90	450	.55	68.8	90	.19	21.4

Example. Halsey-Weir System. Job Rate, 100 hours. 30% of timed saved.

Hours paid $= 100 \times .85 = 85$ hours. Estimated cost exceeded by $6\frac{1}{4}$%.

From One System to Another. Owing, perhaps, to there being more than one system in use in the same works, or to a change being made from one system to another, it is sometimes found necessary to change job rates ensuring, at the same time, that the opportunities for earning shall neither be increased nor decreased.

Where job rates have been based on estimated time, no difficulty arises, but when the basis has been time taken or "experience," the use of a factor will be found of use.

Rowan System to Halsey $33\frac{1}{3}$% System.	Add $\frac{1}{3}$ or $33\frac{1}{3}$% to job rate.
Rowan system to Halsey-Weir 50% system.	Add $\frac{1}{9}$ or 11.1% to job rate.
Rowan system to Plain Premium system.	Deduct $\frac{1}{9}$ or 11.1% from job rate, when plain premium rate is given in terms of time.
Halsey $33\frac{1}{3}$% system to Halsey-Weir system.	Deduct $\frac{1}{6}$ or 16.6% of job rate.
Halsey $33\frac{1}{3}$% system to Rowan system.	Deduct $\frac{1}{4}$ or 25% of job rate.
Halsey $33\frac{1}{3}$% system to Plain Premium system.	Deduct $\frac{1}{3}$ or $33\frac{1}{3}$% of job rate.
Halsey-Weir system to Halsey $33\frac{1}{3}$% system.	Add $\frac{1}{5}$ or 20% to job rate.
Halsey-Weir system to Rowan system.	Deduct $\frac{1}{10}$ or 10% of job rate.
Halsey-Weir system to Plain Premium system.	Deduct $\frac{1}{5}$ or 20% of job rate.

When the job rates on the Plain Premium system have been given in terms of money, the calculation required is of a different character. As previously stated, when the basis of job rates is estimated time, no difficulties arise nor is calculation required, but when the basis is time taken, the time rate of wages as well as the rate of output, is reflected therein. This can be done by the use of the following formula:

$$\text{Sharing system job rate} = \frac{\text{plain premium job rate in pence} \times x}{\text{time rate in pence}}.$$

For the different systems x would have the following values:

Halsey $33\frac{1}{3}$% system - - -	90.
Halsey-Weir 50% system - -	75.
Rowan - - - - - -	67.5

Should it be desired to convert the money job rate to a basis of "estimated" time, the value of x would be 45.

Then assuming a job rate of 1/4—16 pence—which allows time and a third earnings, and a time rate of 1/-, the "estimate" and job rates would be as shewn below:

$$\text{Estimate in minutes} = \frac{16 \times 45}{12} = 60 \text{ minutes.}$$

$$\text{Job rate Halsey } 33\tfrac{1}{3}\% \text{ system} = \frac{16 \times 90}{12} = 120 \quad ,,$$

Job rate Halsey-Weir 50% system $= \frac{16 \times 75}{12} = 100$ minutes.

Job rate Rowan system $= \frac{16 \times 67.5}{12} = 90$,,

In the case of conversion to the Taylor system being required, the estimate only is needed. To this, no addition is necessary, the amount provided for extra pay not being added to the estimate.

APPENDIX No. 1.

BARROW JOINT ENGINEERING TRADES[1]

Procedure to be Observed in Connection with the Adjustment of Premium Bonus Basis Times

Clause 1. Where the job to be performed is the same as on previous occasions, and the means or methods of production has not been changed, the basis time allowed shall be the recognized time for the job. Recognized times shall not be reduced unless the means or method of production has been changed.

Clause 2. Where the work to be performed is not the same, or where the means or method of production has been changed, or where the job is one which has not previously been performed on Premium Bonus System, or one where there is no recognized basis time for the job, the rate-fixer, having seen the job and taken out an estimate of the time to be occupied on the job, will, as soon as possible after the job has been given out, see the workman or workmen who are to perform the work, and give any explanations that may be desired regarding the time allowed. The intention is that the least possible time should be occupied in putting the workman in the position of knowing what his basis time is for the job he is undertaking. The firm agree to make the necessary arrangements to ensure this.

Clause 3. Basis times for new jobs shall be fixed, having regard to the capacity of a workman of average ability. It is recognized that in the case of a new job the workman may be unable to carry out the work as expeditiously as on repeat jobs. To meet this, the firm agree, on the first job, an allowance may be made to the workman should the necessities of the case require this. Such allowance shall be based on the average earnings of the workman concerned for the previous month.

Clause 4. In the event of the workman taking exception to the time allowed, the rate-fixer shall endeavour to convince him of the sufficiency of the time. Should he not succeed, he shall refer the matter to the chief rate-fixer for his opinion, and thereafter again see the workman in accordance therewith.

Clause 5. Failing settlement between the rate-fixers and the workman, the question shall be referred by the rate-fixer to the Appeals Section of the Rate-fixing Department. In order that the claim of the workman may be considered, a form will be supplied to the workman on which he shall state his claim, and hand the form to the representatives to be appointed under Clause 7 hereof, who shall thereafter submit the claim to the Appeals Section in accordance with the procedure. Meantime the job shall be proceeded with. Settlements regarding basis times shall be retrospective to the commencement of the job on which the question is raised, and shall be final and binding on all concerned.

[1] Reprinted from the *Glasgow Herald*, April 25th, 1917, by kind permission of the Editor.

Clause 6. Complaints shall be dealt with by the Appeals Section in their order of priority.

Clause 7. For the purpose of discussion of appeals lodged, two representatives shall be chosen from their own number by each trade in each main department of the works, who shall be authorized by the workman to confer with the Appeals Section of the Rate-fixing Department (composed of two officials of the firm) on questions affecting the trade and department they represent. For example, on a turning question in the Howitzer Department, two turners from that department would confer with the Appeals Section, and similarly in fitting questions two fitters would confer with the Appeals Section. The representative appointed in the terms of this Clause shall be given facilities, if desired, for examining cards and records relating to any question referred to them.

Clause 8. The rate-fixer and the workman concerned may, if desired, be called upon to give evidence.

Clause 9. Failing settlement being arrived at in the proceedings before the Appeals Section, the question may be referred, without further argument, to the Directors for decision.

Clause 10. The foregoing procedure shall be followed in the case of claims for allowance over or above the basis time stated on the job card, and also in cases where in the execution of the job it is necessary to make further estimates of the work to be done.

Clause 11. A portion of the job card containing the principal particulars relating to the job and the basis time shall be detachable, and may be retained by the workmen, if desired.

Clause 12. Detailed Pay Lines.—Pay lines shall be given, on which shall be inserted particulars of the total time worked, the bonus earned, and the allowances and deductions applicable to the pay to which the pay-line refers. A copy of the pay-line shall be given to each workman along with his pay, and shall be retained by him.

Workmen shall be paid on time check, but the firm, on failure to return cards and after warning the workmen concerned, shall be entitled, pending return of the card, to withhold payment of wages due.

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PRINTED IN GREAT BRITAIN BY ROBERT MACLEHOSE AND CO. LTD.
THE UNIVERSITY PRESS, GLASGOW.